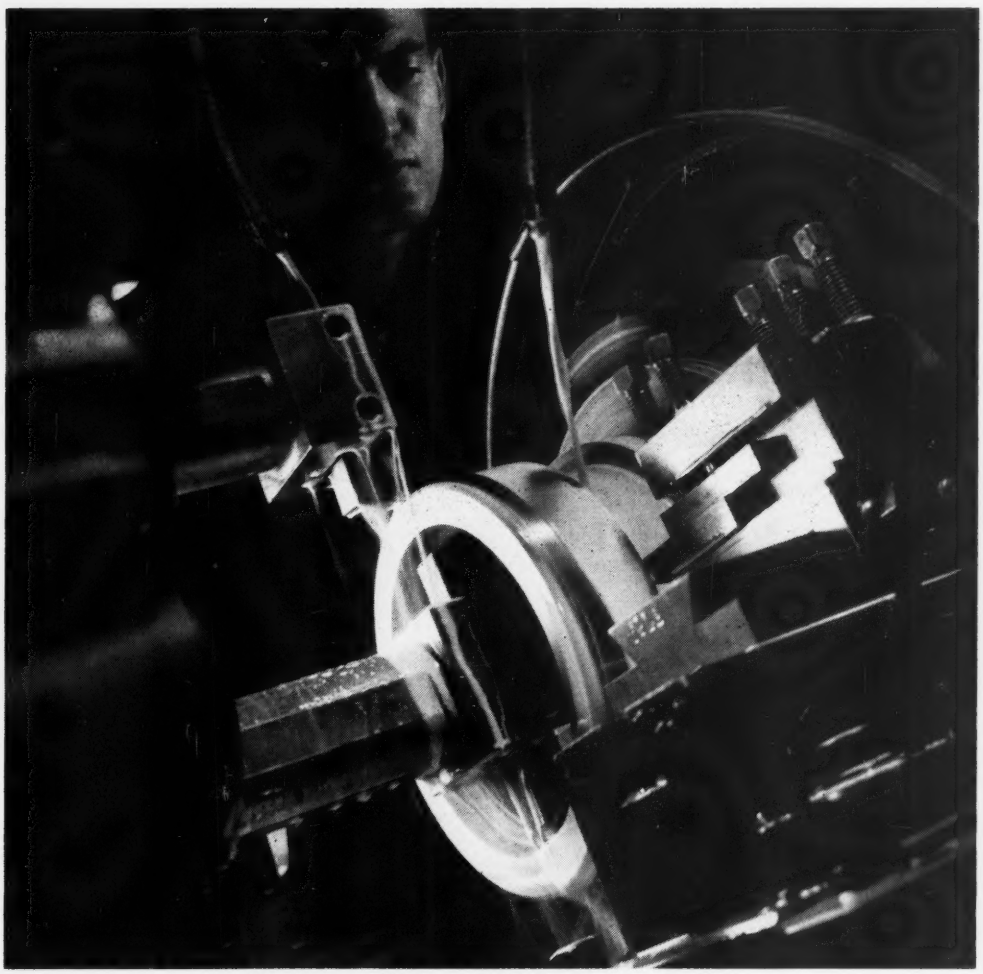
LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE



Machining With A Soluble Cutting Fluid
(Photograph courtesy of Esso Standard Oil Co.)

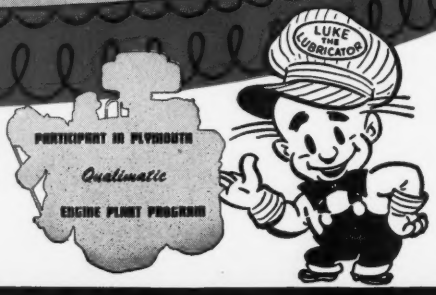
JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS

PRODUCTION INSURANCE

Most of the 400-500 machines in the "Qualimatic" production line are equipped with Trabon auto lube systems

Trabon "QUALIMATIC" LUBRICATION

IN THE WORLD'S MOST MODERN V-8 ENGINE PLANT



Trabon ENGINEERING CORPORATION

1814 E. 40th STREET • CLEVELAND 3, OHIO

Oil and Grease Systems

Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 41874 (Sec. 34.9, P.L.&R.) Chicago, Ill.

LUBRICATION ENGINEERING

American Society of Lubrication Engineers, Publisher

84 E. Randolph St.

CHICAGO 1, ILLINOIS

_____, _____
(Month & Day) (Year)

Gentlemen:

☐ Please enter my subscription for LUBRICATION ENGINEERING for _____ years,

effective with the _____ issue, published bi-monthly.

☐ Please send me information regarding membership in The American Society of Lubrication Engineers*

Regular Subscription $4.00 per year ☐
$7.50 for Two Years ☐
Payment Mailed ☐ Send Bill ☐

Name_____ Title_____

Company _____

Street Address _____

City_____ Zone_____ State_____

With which branch of industry is your company identified:_____

_____

* Note: Membership includes subscription to LUBRICATION ENGINEERING.

ASLE MEMBERSHIP CLASSIFICATIONS

Membership in the American Society of Lubrication Engineers is in several grades as defined below. Assignment to grade is made by the Admissions Committee or Board of Directors on the basis of information submitted or supplied by references.

MEMBERS: Members shall be persons not less than 24 years of age who: (1) are engaged in research and instruction at technical schools, universities, and various publicly and privately supported institutions in the field of lubrication; or (2) have occupied recognized positions as lubrication engineers for a period of three or more (not necessarily consecutive) years prior to date of admission, involving the responsibility for or supervision of the development, selection, field use and application of lubricants as differentiated from other activities; or (3) are indirectly concerned with the field of lubrication, but possessing other qualifications of experience, knowledge, and accomplishment, and have manifested a particular interest in the purposes and welfare of the Society to the extent that their membership would be a valuable contribution to the successful functioning of its activities. Fee $12.50.

ASSOCIATE MEMBERS: Associate Members shall be persons less than 24 years of age, and those who do not completely fulfill the membership requirements for Members. Fee $6.25.

SECTIONAL SUSTAINING MEMBERS: Sectional Sustaining Members are such persons or organizations as may be interested in and desire to contribute to the support of the purposes and activities of a local Section of the Society. Fee $25.00.

INDUSTRIAL MEMBERS: Industrial Members are such persons or organizations as may be interested in and desire to contribute to supporting the purposes and activities of the Society. Fee $150.00.

For application blanks or further information, write:

ASLE
84 E. Randolph St.
Chicago 1, Ill.

LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE

Vol. 11, No. 6 November-December, 1955

Table Of Contents

Adapting The Static Water Drop Test To Research Methods
by E. J. Schwoegler & L. U. Berman 381

Glass Lubricant In The Extrusion Of Steel
by J. Sejournet & J. Delcroix 389

Fluids For The Grinding Of Titanium
by E. J. Krabacher 397

Grease Lubrication Dispensing Equipment, Its Operation & Application
by L. R. McDonald 402

Some Unusual Conditions Encountered In The Lubrication Of Rolling Contact Bearings
by T. W. Morrison 405

Evaluation Of Lubricating Grease Compatibility
by A. L. McClellan & S. R. Calish, Jr. 412

Advertisers' Index 440
ASLE Directory 432
ASLE 11th Annual Meeting & Exhibit, Tentative Program 380
Board Actions 388
Book Reviews, by K. H. Strauss 388
Coming Events 438
Cover Story, submitted by Esso Standard Oil Co. 404
Current Literature 401
Engineering Societies Personnel Service, Inc. 430
Experiment & Experience, by H. E. Mahncke 365
Lube Lines (includes ASLE Progress Report for 1954-55, by J. Boyd) 371
Lubrication Abstracts, compiled by Henry Brutcher 411
Lubrication in the News, submitted by The Atlantic Refining Co. 367
Meet the Authors 363
Men of Lubrication (Lord Rayleigh), by F. R. Archibald 375
New Products 417
Patent Abstracts, compiled by Ann Burchick 418
Personals 418
Section News 396
Subject & Author Indexes for 1955 439

LUBRICATION ENGINEERING is published bi-monthly by the American Society of Lubrication Engineers, 84 E. Randolph St., Chicago 1, Illinois (Phone, DEarborn 2-1293). Current single copies 75c, annual subscription rate $4.00 in the United States and Canada, $4.50 in all other countries.

Copyright 1955 by the American Society of Lubrication Engineers. ASLE will not be responsible for statements or opinions advanced in its meetings or printed in its publications.

Editor ..... R. K. Gould, The Texas Co., 135 E. 42nd St., N. Y. 17, N. Y.
Associate Editor ..... C. R. Kluge, ASLE National Office, 84 E. Randolph St., Chicago 1, Ill.
Consulting Editor ..... A. F. Brewer, Consultant
Advertising and Business Manager ..... W. P. Youngclaus, Jr., ASLE National Office

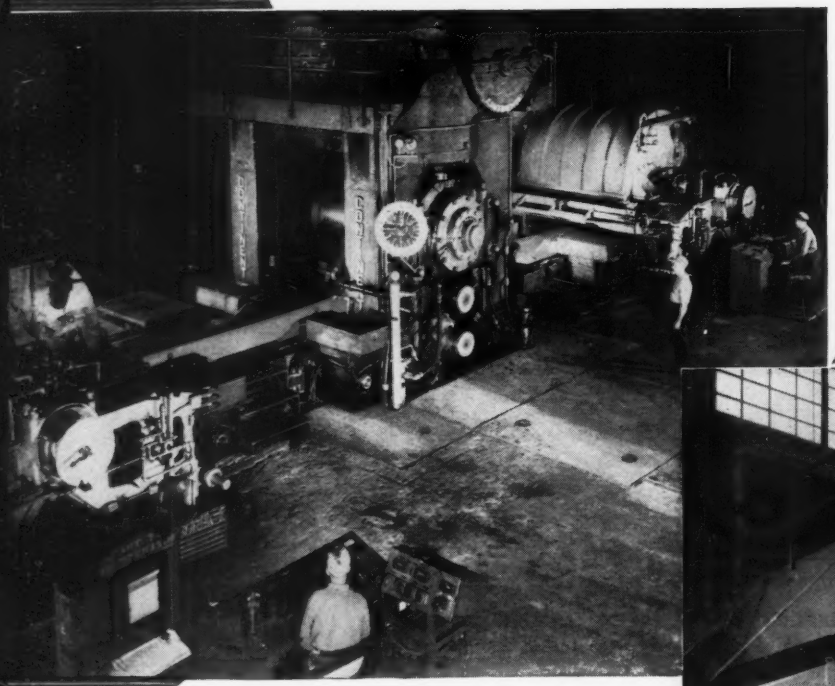
Editorial Committee ..... R. K. Gould (Chairman), The Texas Co.
F. R. Archibald, Arthur D. Little, Inc. ..... D. W. Sawyer, Aluminum Co. of America
R. H. Josephson, Cleveland Graphite Bronze Co. ..... K. H. Strauss, The Texas Co.
H. E. Mahncke, Westinghouse Research Labs. ..... S. K. Talley, Shell Development Co.
J. J. O'Connor, McGraw-Hill Publishing Co. ..... A. C. West, California Research Corp.

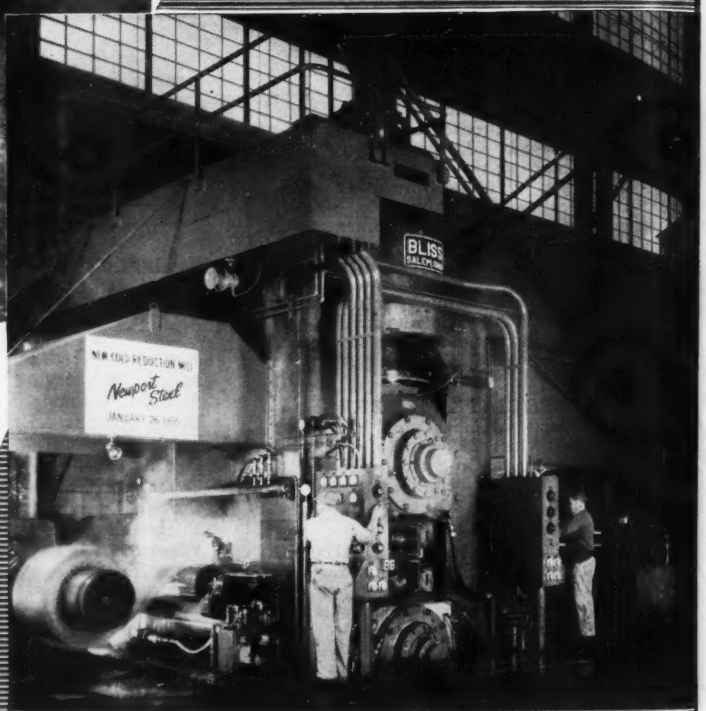
Tables by **Copy Preparation Service,** Chicago, Ill.
Engravings by **Graphic Photo-Engravers** (Chicago), and **The Kentucky Engraving Co.** (Lexington)
Printed by **Publishers Printing Co., Inc.,** 112-116 E. Chestnut St., Louisville 2, Ky.

(Second class mail privileges authorized at Chicago, Ill.)

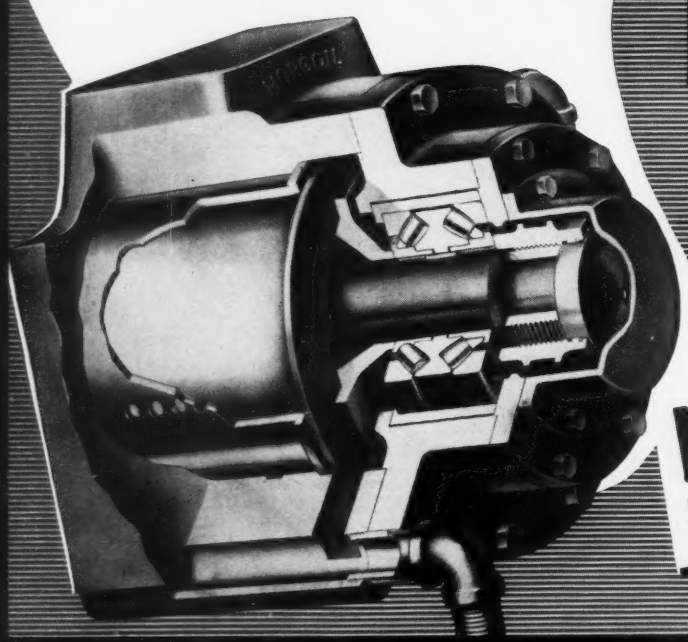
REVERSING MILLS

HOT or COLD





Give Top Performance with MORGOILS



The recent modernization at NEWPORT STEEL CORPORATION, Newport, Kentucky, features a four-high reversing hot mill with Steckel-type furnaces and a four-high cold reduction mill. BOTH mills are equipped with MORGOIL bearings for maximum efficiency.

MB-29

MORGAN WORCESTER

ROLLING MILLS · MORGOIL BEARINGS
GAS PRODUCERS · WIRE MILLS · EJECTORS
REGENERATIVE FURNACE CONTROL

MORGAN CONSTRUCTION COMPANY
Worcester, Massachusetts
English Representative
International Combustion Co., 26 Kingsway, London W.C.2, England

Meet the Authors

Meet the Authors of the papers appearing in this issue of **Lubrication Engineering** (Vol. 11, No. 6). Mr. F. R. Archibald is the author of the series of biographies entitled "Men of Lubrication;" his article in this issue covers the life and accomplishments of Lord Rayleigh. Messrs. E. J. Schwoegler & L. U. Berman, J. Sejournet & J. Delcroix, and A. L. McClellan & S. R. Calish, Jr., are co-authors of their respective papers, i.e. (1) "Adapting The Static Water Drop Test To Research Methods," (2) "Glass Lubricant In The Extrusion Of Steel," and (3) "Evaluation Of Lubricating Grease Compatibility."

L. R. McDonald, p. 402
Wheeling Steel Corp.

T. W. Morrison, p. 405
SKF Industries, Inc.

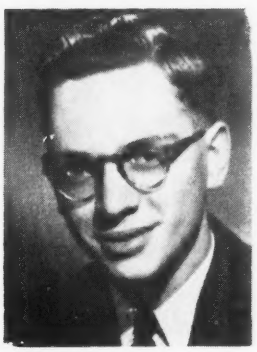
F. R. Archibald, p. 375
Arthur D. Little, Inc.

L. U. Berman, p. 381
Illinois Institute of Technology

E. J. Schwoegler, p. 381
Illinois Institute of Technology

J. Sejournet, p. 389
Comptoir d'Etirage (Paris, France)

S. R. Calish, Jr., p. 412
California Research Corp.



J. Delcroix, p. 389
Comptoir d'Etirage (Paris, France)

E. J. Krabacher, p. 397
The Cincinnati Milling Machine Co.

A. L. McClellan, p. 412
California Research Corp.

Grafo

Lubricants Aid In Protecting Parts of New Atomic Sub

Parts of the new atomic submarine Nautilus were protected with a Grafo Colloidal dry film lubricant. Grafo products were tested and found the most ideal for this work. Whether you have need for lubrication of fine watch tools or large forging presses you, too, will find Grafo Colloids the finest and most economical to use. Write today for complete details concerning Grafo colloidal dispersions.

Grafo Lubricants are Often Imitated but Never Excelled

Grafo COLLOIDS CORPORATION
269 WILKES PLACE
SHARON, PENNSYLVANIA

TRUCK LEASING COMPANY, PORTLAND, MAINE

reports

"Crankcase maintenance greatly reduced"

with

SHELL RIMULA OIL

TRUCKS operated by the Truck Leasing Company, Portland, Maine, have the problem of engines that idle a large part of the time. This type of low-temperature operation calls for an oil of outstanding stability . . . one that combats the acids and contaminants responsible for excessive wear and overhauls. That's why this prominent leasing company uses Shell Rimula Oil in the crankcase.

There are important advantages for fleets in every class of service.

SHELL RIMULA OIL:

- **Reduces engine wear**
- **Minimizes sludging**
- **Reduces lacquering**
- **Increases engine life**
- **Lowers maintenance costs**

If your fleet units operate under severe service conditions, call the Shell office in your area. We will be glad to give you the latest technical data on Shell Rimula Oil for fleet use.

SHELL

SHELL OIL COMPANY

50 WEST 50TH STREET, NEW YORK 20, NEW YORK
100 BUSH STREET, SAN FRANCISCO 6, CALIFORNIA

Experiment & Experience

Gas Flow Through Sealed Ball Bearings, by Dr. H. E. Mahncke (Westinghouse Research Labs., East Pittsburgh, Pa.).

In the course of studying the loss of lubricant from sealed bearings, there arose a question as to the amount of air (or other gas) which would flow through the bearings. Obviously, this can be related to the rate of lubricant volatilization. Since the desired information was not available in the literature or elsewhere, a short experimental program was undertaken at this laboratory. A resume of this work is presented here as it is felt that the simplicity of the apparatus and the striking nature of the results will have applicability to similar problems in lubrication engineering.

Fig. 1 shows a sketch of the apparatus used. Briefly, a test bearing (1) is mounted in a steel plate (2) and possible air flow past the outer race eliminated by means of a circular clamp (3) and a rubber gasket (4). The inner race is attached to the shaft (5) by means of a similar clamp (6) and a ring (7). The shaft is connected to a support bearing (8) and a drive pulley (9) by means of a flexible coupling (10). A flanged air chamber (11) of welded construction, equipped with a gas inlet (12) is bolted to the plate holding the bearing, and sealed by means of an 0 ring (13). Gas is supplied to the system either from a tank or from the laboratory air line through a flow meter. The pressure differential across the bearing is measured with a dibutyl phthalate manometer placed in the supply line.

Some typical results are shown in Fig. 2 for two bearings of the same size and lubricated with the same grease but equipped with different seals. A log-log plot is used to afford a good comparison between the two bearings. If a linear scale is used, it is found for these two bearings that a curve is obtained which shows a finite intercept on the pressure axis, and which becomes a straight line at relatively high rates of flow. This gives rise to the possibility of deriving some numbers to express the quality of the seals, effect of grease charge, speed, cage design, and other factors in terms of the amount of air passed under constant conditions.

For example, let us arbitrarily select a 10 mm pressure difference as a standard pressure. Then, by extrapolation, we find a value for the rate of flow of air through each bearing. Bearing A (3600 and 1750 rpm), 25 cc/min.; Bearing B (3600 rpm), 32,000 cc/min.; Bearing B (1750 and 0 rpm), 60,000 cc/min. Relative rates of oil evaporation would be roughly proportional to these figures. It should be noted, however, that since the lines may have different slopes, ratios of this sort will vary with the choice of the comparison pressure.

One may also use this data to calculate an equivalent clearance from the formula for rate of flow through an annulus.

$$Q = \frac{\pi \Delta P r_1 (r_2 - r_1)^3}{6 \mu l}$$

(Continued on p. 367)

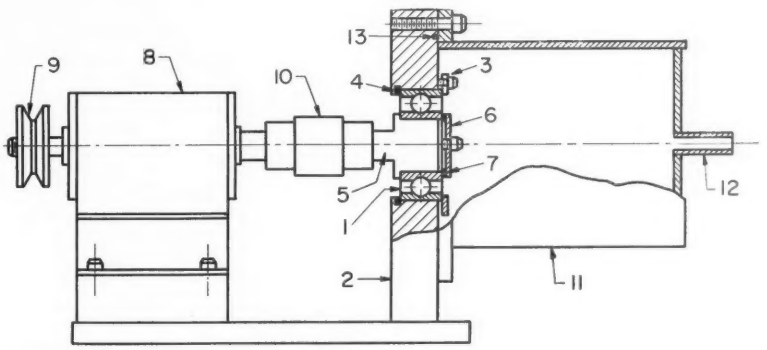


Fig. 1. Flow rate bearing tester.

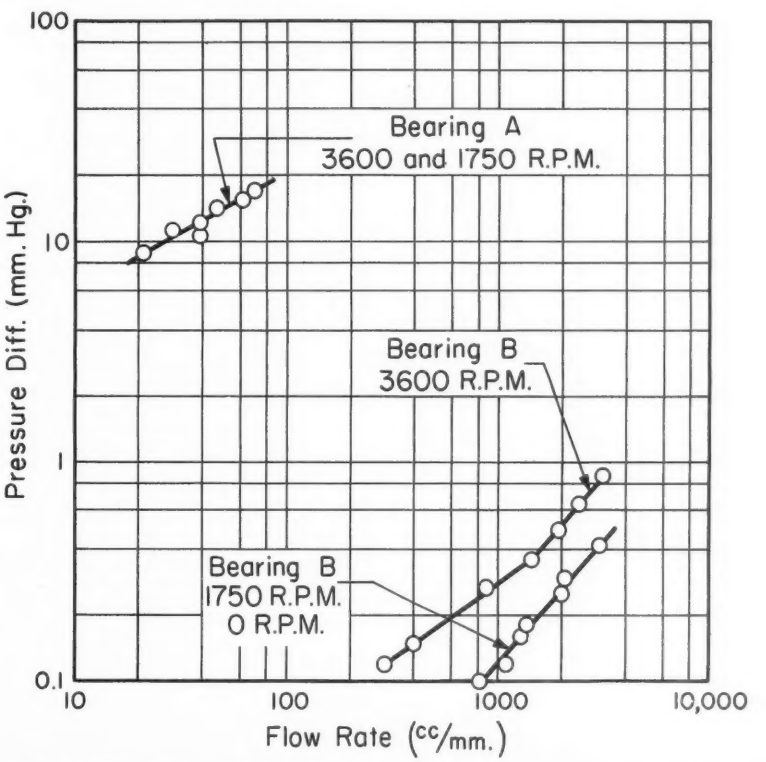
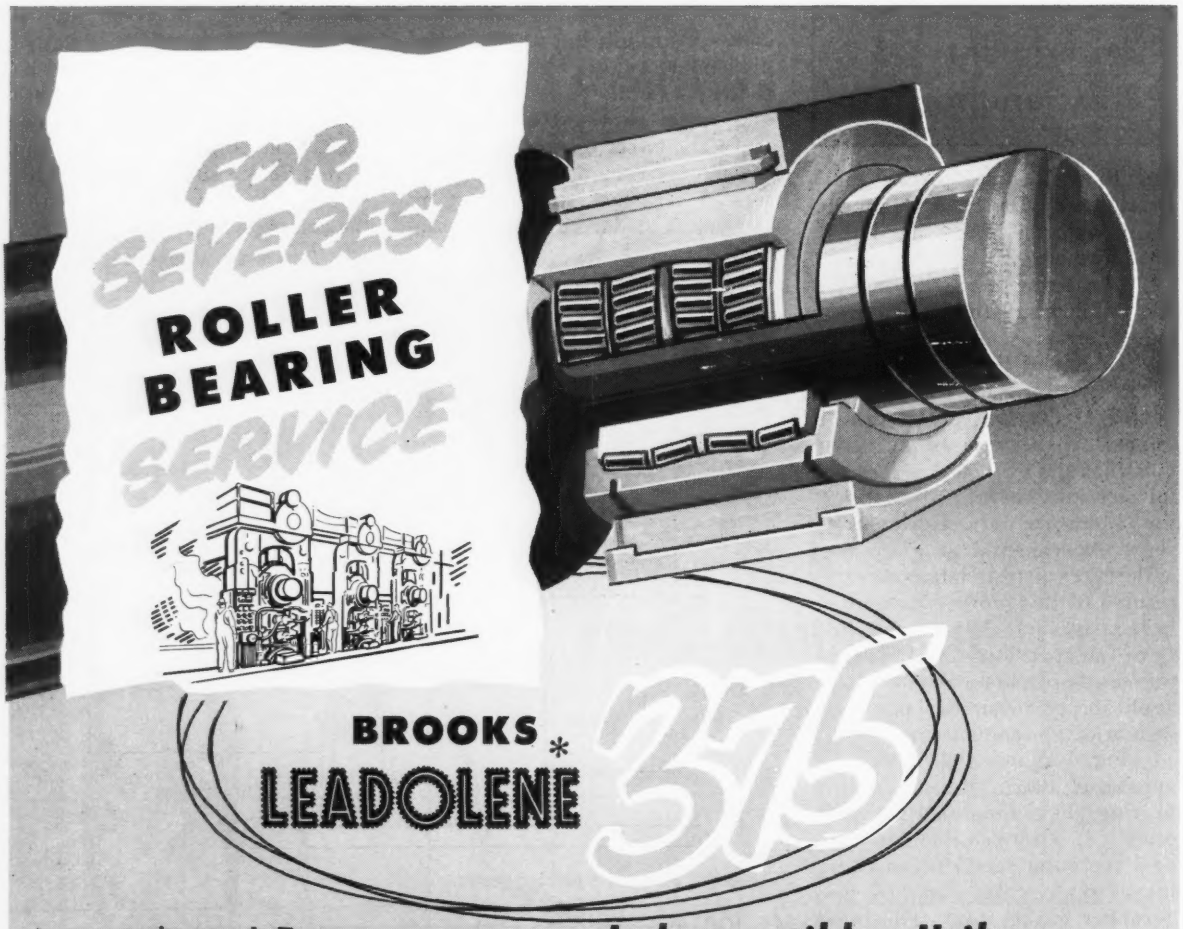


Fig. 2. Gas flow through bearings.



*THE I.P. LUBRICANT WITH *Indestructible pH-ilm*

Brooks Leadolene 375 provides safe, trouble-free lubrication of roller bearings under heaviest loads, overloads and severest shock conditions, such as experienced in heavy duty work roll service on 4 high hot strip mills, reduction mills and temper pass mills. Developed through years of research, this modern industrial lubricant provides corrosion resistance to component parts of bearing from cooling water and other contaminating actions.

Available in three grades . . .

Leadolene 375 Light: For normal or moderately high temperatures, with repellence of water a dominant factor. Excellent pumpability.

Leadolene 375 Medium: For heavier load and higher temperature requirements. Prevents leakage through seals. Excellent pumpability. Affords year around service under all temperature conditions.

Leadolene 375 Heavy: For pressure gun or system applications in normal or high temperatures. Good pumpability.

A Brooks lubrication engineer will gladly call at your request. Write, phone or wire today.

THE BROOKS OIL COMPANY
934 Ridge Avenue
Pittsburgh 12, Pa.

Please send bulletin on Leadolene 375.

NAME_____

TITLE_____

COMPANY_____

ADDRESS_____

CITY_____ ZONE____ STATE_____

L. E. 12-55

MAIL COUPON FOR COMPLETE DATA

The Brooks Oil Company

Since 19

Executive Offices and Plant, Cleveland, Ohio
Executive Sales Offices, Pittsburgh, Pa.
Canadian Offices and Plant, Hamilton, Ontario
Cuban Office, Santiago de Cuba
Warehouses in Principal Industrial Cities

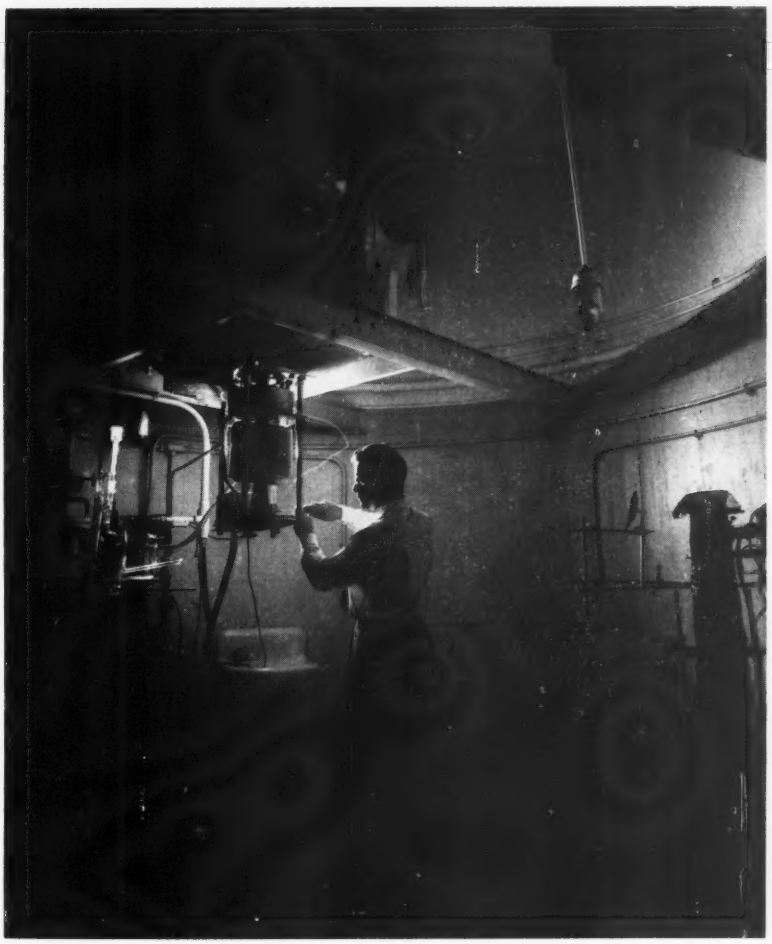
where Q = volume rate of flow, ΔP = pressure differential, r_1 = inner radius of annulus, r_2 = outer radius of annulus, l = length of annulus, μ = gas viscosity.

This assumes laminar flow which probably does not prevail. However, equivalent clearances calculated by this means will be on the low side. Either this or the actual flow rate at a given pressure may be used to compare the effects of such variables as grease charge, speed, seal design, cage design, etc.

Lubrication in the News

New Atomic Particle Accelerator. "Atomic radiation may prove to be the next step in petroleum processing," predicts Dr. H. W. Field, Vice-President for Research & Development of The Atlantic Refining Co.

Up to now the petroleum industry has relied largely on heat, along with pressure and catalysts, to break the petroleum molecules apart and reform them into more potent fuels, lubricants, and chemicals. (Heat tends to shatter the molecules into a variety of fragments; from this mixture, the useful pieces must be chosen and separated for further processing.) Already experimenting with atomic radiation as a promising new tool for refining crude oil, Atlantic is now operating a radiation source of its own at its Philadelphia Laboratories—the first industrial linear atomic accelerator on the east coast. "With atomic energy" Dr. Field explains, "we hope to neatly snip the molecule into the exact pieces we want, without wasted fragments."



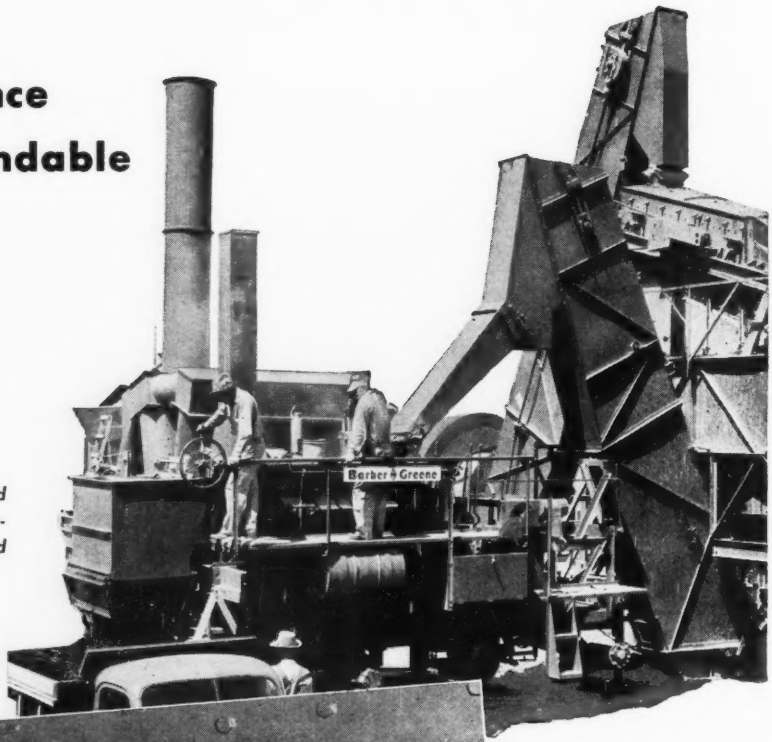
To study the effect of atomic radiation on the processing of petroleum products, including petrochemicals, this electron gun (a one-million volt resonance transformer manufactured by the General Electric Co.) speeds atomic particles through magnetic coils to reach velocities up to 600 million miles per hour or more as they are shot into petroleum hydrocarbons. (Dr. Vincent J. Keenan, Chemical Research Supervisor, is shown adjusting the gun's aperture through which the electrons will shoot.) The energy output of the gun is flexible and can be varied by adjusting a few dials on its control panel; any stray radiation is trapped by the thick concrete walls of the tower in which the gun is housed.

During operation the scientists are protected by elaborate interlocking switch circuits which automatically shut off the gun if any of the lead-lined doors in the tower or control room are opened. In the tower wall a viewing port, made from two plates of glass separated by 18 inches of zinc bromide solution, safely stops radiation when observing the reactions occurring under the gun.

In commenting on the radiation sources available for research, Dr. Field states: "Radioisotopes made in atomic reactors are being used at some industrial laboratories for radiation sources; even more powerful radioisotopes are on the way, the rapid developments in atomic reactor design promising greater economy and efficiency. Not to be left behind, the manufacturers of particle accelerators are working vigorously to improve their machines. At this point we do not know which will win out, so we intend to continue to experiment with all types of atomic radiation." (Submitted by The Atlantic Refining Co.)

11th ASLE Annual Meeting Pittsburgh April 4-5-6, 1956

machines of great performance use the most dependable oiling system ever developed



A Model 50 Madison-Kipp Lubricator installed as original equipment on a Model 848 Barber-Greene Asphalt Mixing Plant manufactured by Barber-Greene Co., Aurora, Illinois.

MADISON-KIPP *Fresh Oil*

. . . by the measured drop, from a Madison-Kipp Lubricator is the most dependable method of lubrication ever developed. It is applied as original equipment on America's finest machine tools, work engines and compressors. You will definitely increase your production potential for years to come by specifying Madison-Kipp on all new machines you buy where oil under pressure fed drop by drop can be installed. There are 6 models to meet almost every installation requirement.

kipp

MADISON-KIPP CORPORATION
223 WAUBESA STREET • MADISON 10, WIS., U.S.A.

• **Skilled in Die Casting Mechanics** • **Experienced in Lubrication Engineering** • **Originators of Really High Speed Air Tools**

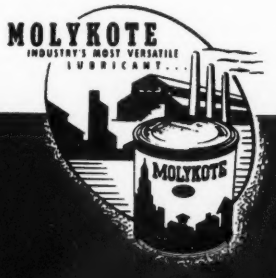
REDUCE galling, seizing and wear

with MOLY-Spray-KOTE®

LUBRICANT

Convenient Application . . . Especially For Hard-To-Get-At Locations

MOLY-Spray-Kote is one of industry's most effective dry lubricating films. It is a carefully compounded dispersion of microfine molybdenum disulfide powder in a propellant and packaged in a self-pressurized aerosol-type sprayer. Here is positive protection from seizing, welding and galling of metal parts . . . especially if applied during assembly.

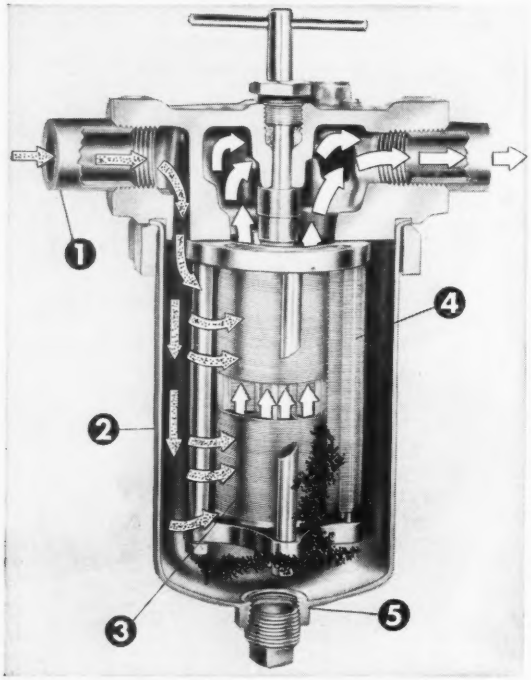


Send for a trial order today.
Write for your free copy of our new Bulletin 102 on MOLY-Spray-KOTE.

THE ALPHA CORPORATION

65 HARVARD AVENUE, STAMFORD, CONN.

New CUNO SUPER Auto-Klean Filter can boost engine life up to 50%



HOW IT WORKS. Dirty oil enters inlet (1) at left, fills housing (2) and flows through metal edge-type filter. (3) Clean oil rises through center of filter, leaves at right. Dirt combed out by cleaner blades (4) is removed through drain (5).

Here's what the U.S. Army has done to test Cuno's new 40-micron SUPER Auto-Klean filter for their engines:

They ran destruction tests on several identical engines equipped with different brands of filters. As they ran, dust was introduced into the air intakes. When compression fell to half its initial value, the test was stopped. Best life for engines equipped with cartridge-type filters was 60 hours.

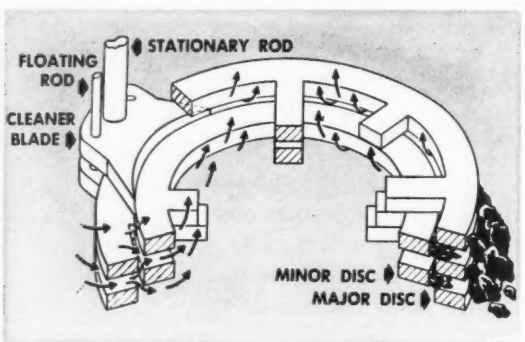
The engine with SUPER Auto-Klean ran 90 hours—50% longer—and *compression was still above half its initial value!*

You can get SUPER Auto-Klean now!

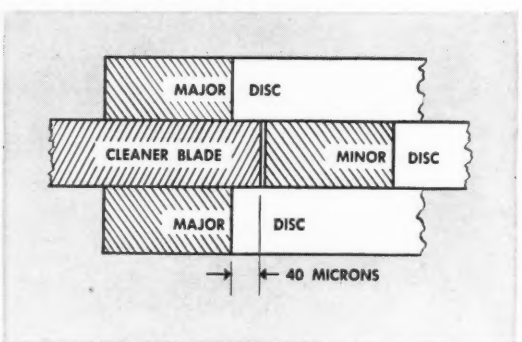
Just specify that the manufacturer equip your new diesel with this latest and best in filtration—both for fuel and full-flow lube. You'll get longer engine life and . . .

1. **Full-Flow** 40-micron filtration with a self-cleaning filter. No cartridge changes; filter can't rupture or channel.
2. **Low pressure drop.** An 8- by 2¼-inch filter element handles 30 gpm of 200 SSU lube oil with only 3 psi pressure drop. You get high capacity in a small package.
3. **All metal.** Can't absorb or adsorb additives from oil.
4. **No interruptions for cleaning.** Handles full flow all the time.
5. **Standard Auto-Klean housing.** On existing engines you can easily replace most 2¼ in. diameter cartridges with SUPER Auto-Klean or simply install SUPER Auto-Klean in the full-flow lube line following the discharge of the engine pump.

Write today for complete technical data on the new SUPER Auto-Klean for your new or existing diesel. Ask for Catalog No. SAK-057. Cuno Engineering Corporation, 13-11 South Vine Street, Meriden, Connecticut. 5.5



FILTER ELEMENT consists of stacked major and minor discs and cleaner blade bearing against precision ground minor disc. Oil flow is shown by arrows.



LARGE PARTICLES (over 0.012 in.) are stopped at space between major discs. Short 40-micron restriction stops 40-micron particles, but allows high flow rate.

CUNO

ENGINEERED FILTRATION

Removes More Sizes of Solids From More Kinds of Fluids

AUTO-KLEAN (edge-type) • MICRO-KLEAN (fibre cartridge) • FLO-KLEAN (wire-wound) • PORO-KLEAN (porous metal)

Lube Lines

ASLE PROGRESS REPORT for 1954-55, by J. Boyd, Westinghouse Research Laboratories (Chairman of the ASLE Presidential Council). Measured by all the usual standards, the 1954-55 fiscal year was one of the most successful in the history of the Society. Most previous records were broken. This was accomplished by the combined efforts of a multitude of individuals who contributed their time, their energy, and their enthusiasm.

ASLE is still a relatively young society and, while it has already taken its place as one of the important engineering organizations, a special effort was made during the year to more clearly set forth the scope of its interests and to make certain that the Society establishes a reputation for service and high technical standing.

Since the term "lubrication" is sometimes used in a very restricted sense, the Society's interests were clarified to include any activity associated with the control of friction or the control of wear. The words "Research, Application, Education," and "Maintenance" were incorporated on a new cover design for **Lubrication Engineering** to indicate that the Society is equally concerned with each of these fields and not in just one or two with the exclusion of any of the others. In addition to this, the Society went on record as striving to publish the foremost journal in the field. It is attempting to do this by: (1) Efficiently and impartially covering all phases of lubrication engineering as implied in the broadest interpretation of the term; (2) Matching the editorial and typographical quality of the best publications in this or similar fields; (3) Prompt publication; and (4) Incorporating suitable reader service features.

Participation in joint programs with other engineering societies was initiated with a Conference on Lubrication held in Baltimore and jointly sponsored by ASME and ASLE. This meeting was so successful that it was decided to hold a similar conference in 1955.

Arrangements were concluded with McGraw-Hill Book Company for the publication of a Standard Handbook of Lubrication Engineering.

Increase in membership continued at about the same rate as for the last two years. A new section was formed at Louisville, Kentucky, taking over some of the district previously assigned to the Evansville section which was discontinued.

The reserve account continued to grow toward the goal of one year's operating expense with an addition of $10,000 from surplus. A separate fund was established for the purpose of supporting fellowship, scholarships, and research.

Four new general committees were added. These included the Handbook Advisory Committee to handle arrangements for the publication of the handbook; the Industry Advisory Committee to give special consideration to the needs of industry; the Abstracts Committee to handle abstracts for the journal; and the Organization & Operations Committee to survey the Society structure for the purpose of improving efficiency and making the best use of our available manpower. A new subcommittee on Gear Lubrication was added to the General Technical Committee.

The following statistics will help to round out the picture of the Society's activity during the year:

Memberships, regular as of 5-1-55	2638
Memberships, industrial as of 5-1-55	35
Reserve account as of 4-12-55	$42,555
Attendance, Annual Meeting	1407
Papers presented at Annual Meeting	50
Exhibitors at Annual Meeting	32
Attendance, A. M. Exhibits	3488
Attendance, A. M. Lubrication Course	98
Attendance, Joint Conference	282
Papers presented at Joint Conference	18
Sections visited by President	15
Technical talks given by President	13

In submitting this report I wish to express my appreciation for the many pleasant associations I enjoyed during my tenure as President, and to acknowledge the active support of my Company which made this association possible. (Editor's Note: Copies of the complete Annual Report can be obtained by writing the ASLE National Office.)

The Process of Lubrication. Lubrication, as the essential medium for protecting moving parts of machinery and insuring against abnormal wear, is relatively young in theory but ages-old in practice. The theory dates back to the studies of Beauchamp Tower reported in 1883. The practice of lubrication, however, ante-dates the Christian Era by many centuries. Beef and mutton tallow were used for lubricating the axles of chariot wheels when the age of mechanized warfare was born. Animal and vegetable oils continued in usage as lubricants when subsequent mechanisms were developed, until the age of petroleum came into being with the Drake well in 1859.

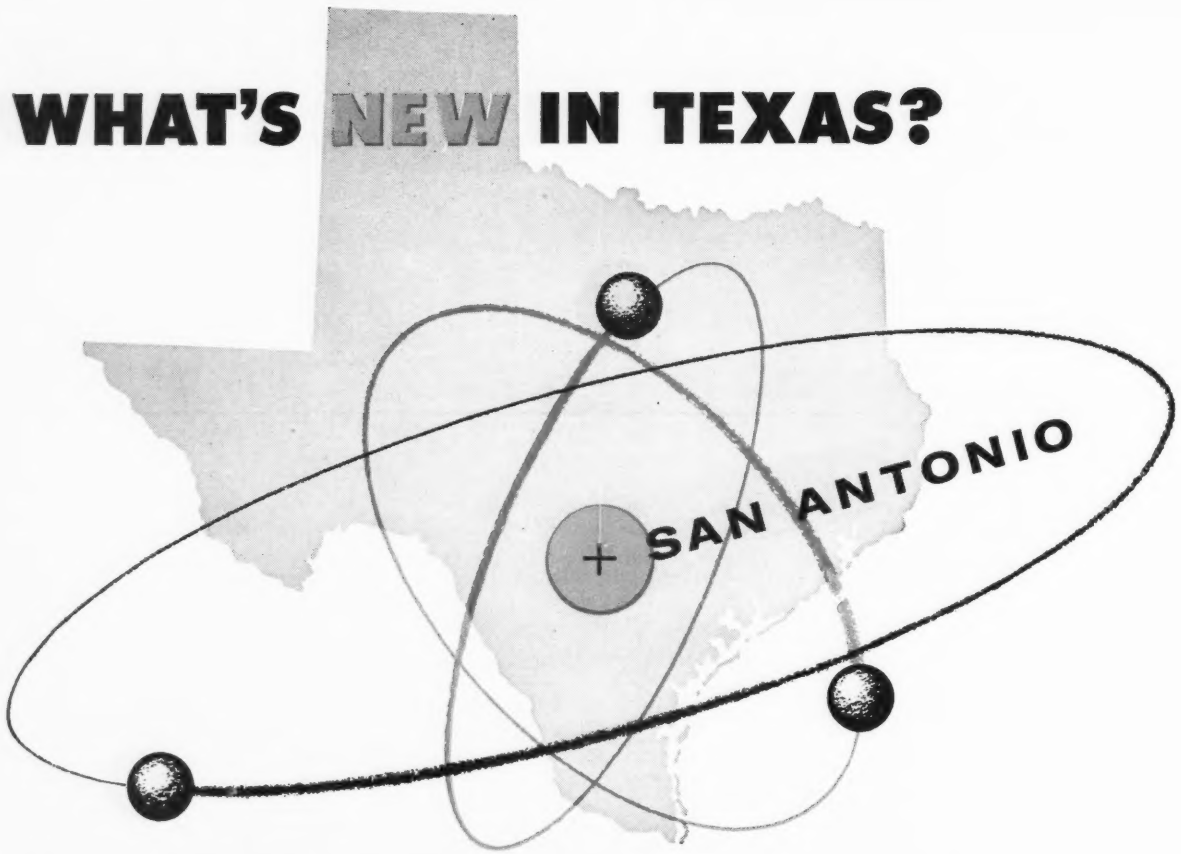
The process of lubrication is as essential to modern machinery as the materials which go into the make-up of these machines. Lubrication protects the moving contact parts against abnormal friction and wear; lubrication assures that transportation, mass production, and power generation are economically and dependably attained.

The relative economic value of the process of lubrication, however, often is lost sight of in view of the comparatively low cost in contrast with the cost of the machine or the power consumed for its operation. If the cost of maintenance is considered, the importance of lubrication immediately becomes outstanding, because the cost of maintenance basically depends upon how much consideration is given to the cost of lubrication.

Low-grade lubricants unsuited for the operat-

(Continued on p. 422)

WHAT'S NEW IN TEXAS?



NEW SOURCE OF

Lithium Hydroxide

FOR *Producers of*
LITHIUM-BASED GREASES

The new $6,600,000 plant of American Lithium Chemicals, Inc. in San Antonio, an affiliate of American Potash & Chemical Corporation, long the leading producer of Lithium Carbonate, makes available to producers of lithium-based greases an abundant new source of supply of LITHIUM HYDROXIDE. The new plant will process high-grade lithium ores from extensive deposits in Southern Rhodesia, assuring you of vast reserves, coupled with the most modern domestic production facilities available anywhere. You can count on the advantages of Trona LITHIUM HYDROXIDE in your all-purpose greases—moisture resistance, chemical and mechanical stability and wide temperature range, just as you can depend on the consistent good quality of Trona's new source of this vital all-purpose, all weather grease additive.

Send for technical information sheet

FOR LITHIUM CHEMICALS—LOOK TO AMERICAN POTASH!

TRONA
INDUSTRIAL AND AGRICULTURAL CHEMICALS
ESTON CHEMICALS

American Potash & Chemical Corporation

Offices • 3030 West Sixth Street, Los Angeles 54, California
• 99 Park Avenue, New York 16, New York
• 214 Walton Building, Atlanta 3, Georgia
Plants • Trona and Los Angeles, California and San Antonio, Texas
Export Division • 99 Park Avenue, New York 16, New York

LITHIUM CARBONATE • LITHIUM HYDROXIDE • LITHIUM BROMIDE • LITHIUM CHLORIDE and other LITHIUM CHEMICALS

KLOZURE* OIL SEALS

USED EXCLUSIVELY on RBC's new Sealed "Pitchlign" Roller Bearings

Springless KLOZURE Oil Seal Model 71-A, with synthetic rubber sealing member securely bonded to and integral with a metal case.

In designing their new sealed "Pitchlign" roller bearing, the Roller Bearing Company of America (W. Trenton, N. J.) needed a proven, dependable oil seal of narrow cross section.

RBC engineers selected springless KLOZURE Model 71-A. They found this superior seal was specifically designed for limited space applications. In addition, Model 71-A had proved on thousands of applications that it would keep out dust and retain the lubricant for the *life of the bearing.*

Let us show you how Garlock KLOZURES can solve your sealing problems. There's a proven KLOZURE model for every bearing application.

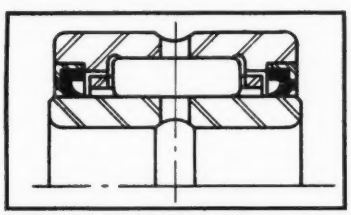
For full information contact the Garlock office nearest you or write for KLOZURE Catalog No. 10.

*Registered Trademark

THE GARLOCK PACKING COMPANY, PALMYRA, NEW YORK

Sales Offices and Warehouses: Baltimore, Birmingham, Boston, Buffalo, Chicago, Cincinnati, Cleveland, Denver, Detroit, Houston, Los Angeles, New Orleans, New York City, Palmyra (N. Y.), Philadelphia, Pittsburgh, Portland (Oregon), Salt Lake City, San Francisco, St. Louis, Seattle, Spokane, Tulsa.

In Canada: The Garlock Packing Company of Canada Ltd., Toronto, Ont.

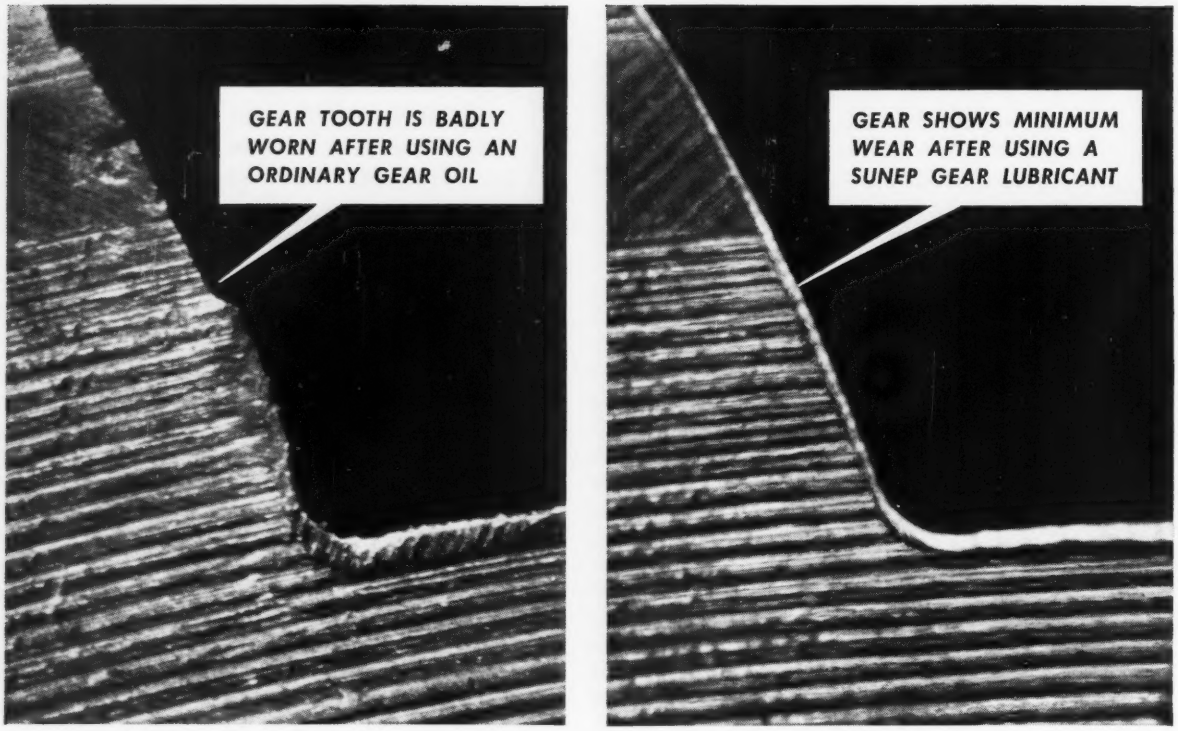


Two springless KLOZURES, lips turned in, on "Pitchlign" bearing provide life-time retention of the lubricant.

RBC's new sealed "Pitchlign" roller bearing with two built-in springless KLOZURES.

GARLOCK

PACKINGS, GASKETS, OIL SEALS
MECHANICAL SEALS
RUBBER EXPANSION JOINTS



COMPARATIVE TESTS on identical new worm gears demonstrate superiority of Sunep Gear Lubricant. Gear on left, using a compounded cylinder oil, shows excessive wear at 70 hours. Gear on right, protected by Sunep, shows minimum wear after running over 200 hours!

HERE'S PROOF SUNEP GEAR LUBRICANTS MINIMIZE WEAR

Sunep Gear Lubricants cut power losses... protect against overloads ...lengthen gear life...reduce maintenance costs and replacements.

During recent tests gear units protected by Sunep Gear Lubricant showed an absolute minimum of wear when run at normal rated capacity. There was no indication of scoring or wear even when run at overloads up to 118%! Power consumption was reduced up to 25%. Damage from shock loads was nil.

In addition to outstanding load-carrying ability, Sunep Gear Lubricants are extremely stable, non-corrosive, prevent rusting, keep gears and bearings clean.

For complete information about how Sunep Gear Lubricants can help give longer life to your worm gear units, see your Sun representative...or write SUN OIL COMPANY, Philadelphia 3, Pa., Dept. LE-12.

SUNOCO®

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY PHILADELPHIA 3, PA.

IN CANADA: SUN OIL COMPANY, LTD., TORONTO AND MONTREAL

Men of Lubrication

(Reproduced by permission of Edward Arnold & Co.)

LORD RAYLEIGH (John William Strutt). Lord Rayleigh was born John William Strutt, the eldest son of the second Baron Rayleigh of Terling Place, Witham, in the county of Essex. He was born in 1842. His early education was greatly hampered by ill health and after short periods at Eaton and Harrow, the traditional schools for the sons of peers, he was placed at a small private school where he received the principal part of his elementary education. He entered Trinity College, Cambridge, in 1861 where he studied under Sir George G. Stokes, Lucasian Professor of Mathematics (the chair held by Sir Isaac Newton), and E. J. Routh, well known for his work in dynamics. Before entering Cambridge Rayleigh had shown great promise in mathematics, and his subsequent university career was brilliant.

Rayleigh's place in science is so important that it seems presumptuous to write about him as a man of lubrication. However, his connection with this science is an intimate one, and he seems to have had a considerable and lasting interest in the subject. He was a personal friend of Beauchamp Tower; the friendship dating from an association during the years 1875-76 when Tower acted as his assistant in his laboratory for a few months. Thereafter, Tower was a frequent visitor at Rayleigh's home until his (Tower's) death in 1904. During the period of this friendship with Rayleigh, Tower carried out the famous experiments on friction for the Institution of Mechanical Engineers, and Rayleigh must have heard about the anomalous results Tower had observed. Moreover, Rayleigh was a member of the committee on friction at high velocities of the Institution of Mechanical Engineers and also an honorary member of this Institution, and it is quite possible that the choice of Tower for the work was due to Rayleigh's knowledge and good opinion of him.

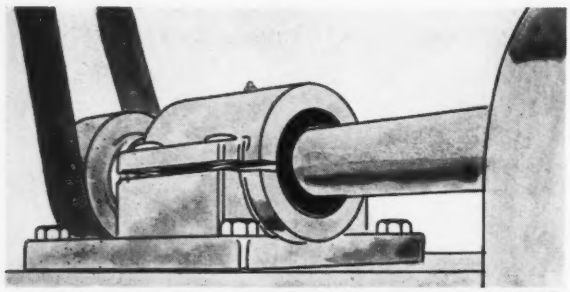
In the first article of this series, Rayleigh's statement about the requirement for the shape of the fluid film in hydrodynamic lubrication, to the British Association Meeting in 1884, was given. He pointed out, apparently for the first time, that hydrodynamic pressure generation requires a convergence of the film from the "ingoing" to the "outgoing" sides. Following this first close association, Rayleigh does not seem to have made any other contributions to lubrication science until toward the end of his life. In 1917 he published in "Engineering" for December 14 an article, "A Simple Problem in Forced Lubrication," in which he solved the problem of the externally pressurized footstep bearing. This seems to be the first article on what is sometimes called hydrostatic lubrication. Again, in 1918, Rayleigh made a thorough study of the plane slider bearing for the condition of no side leakage. This paper appeared in the "Philosophical Magazine." In it he applied the calculus of variations to find the film shape which would support the greatest load if shoe length and minimum film thickness are constrained. The result was to show that a film with a parallel-stepped convergence supports the greatest load.

It is impossible to give an adequate summary of Lord Rayleigh's work in such space as is here allotted. Those who are interested in a detailed account of his life will find his biography by his son, the Fourth Baron Rayleigh, delightful reading. But even this full-scale biography does not attempt to describe the very large number of his more severely technical contributions which have little popular appeal.

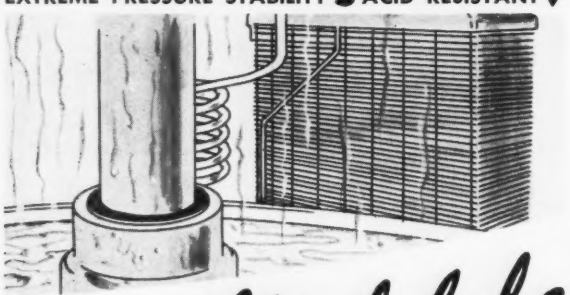
Rayleigh's famous book, "The Theory of Sound," was started by him in 1872 but did not appear until 1877. It is one of the great scientific treatises and is still the outstanding work in its field. But "The Theory of Sound" is much more than a specialized work in acoustics. The whole of the first volume is devoted to the subject of vibrations, and contains much original work of the greatest importance in physics and engineering. His invaluable energy method for approximating the lowest frequency of vibration of complicated systems appears here for the first time, as well as other fundamental theorems in the vibration of dynamical systems. Rayleigh's devotion to the subject of sound extended over his entire career. In addition to "The Theory of Sound," he published well over a hundred papers on acoustics which deal with problems of the greatest significance. He seems to have had

(Continued on p. 420)

Specialized **LUBRICATION** can Solve your Problems



EXTREME PRESSURE STABILITY ▲ ACID RESISTANT ▼

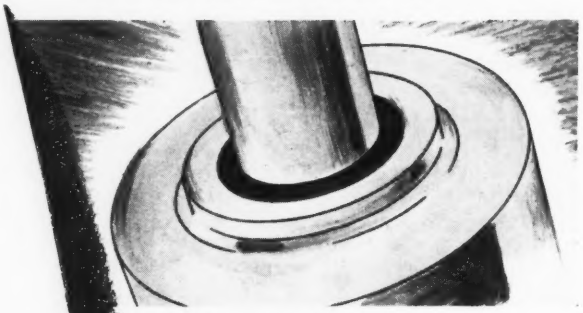


BEL-RAY has pioneered in the manufacture of special lubricants to meet the many difficult lubricating problems of industry. Our Engineers can recommend the right lubricant for *your* particular requirement. Some of the many BEL-RAY lubricants available:

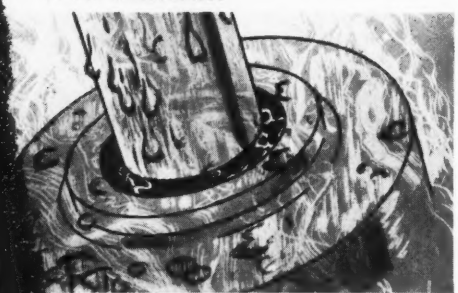
- **HIGH TEMPERATURE LUBRICANTS**
- **LOW TEMPERATURE LUBRICANTS**
- **EXTREME PRESSURE LUBRICANTS**
- **NON-MELTING GREASES**
- **MOLYLUBE SERIES (MOLYBDENUM DISULFIDE)**
- **SPECIAL PURPOSE GREASES**
- **OVEN CHAIN LUBRICANTS**
- **DEVELOPERS OF SPECIAL APPLICATION LUBRICANTS**

Molylube ANTI-SEIZE

This extraordinary lubricant is a highly concentrated non-melting molybdenum disulfide grease having the capacity to prevent galling and seizing at bearing pressures well over 100,000 pounds per square inch. It has excellent lubricating qualities at low temperatures and elevated temperatures up to 750°F.



HEAT RESISTANT



STEAM AND WATER RESISTANT

SEND for FREE SAMPLE tube of this amazing new lubricant.

BEL-RAY CO., INC. Special Lubricants

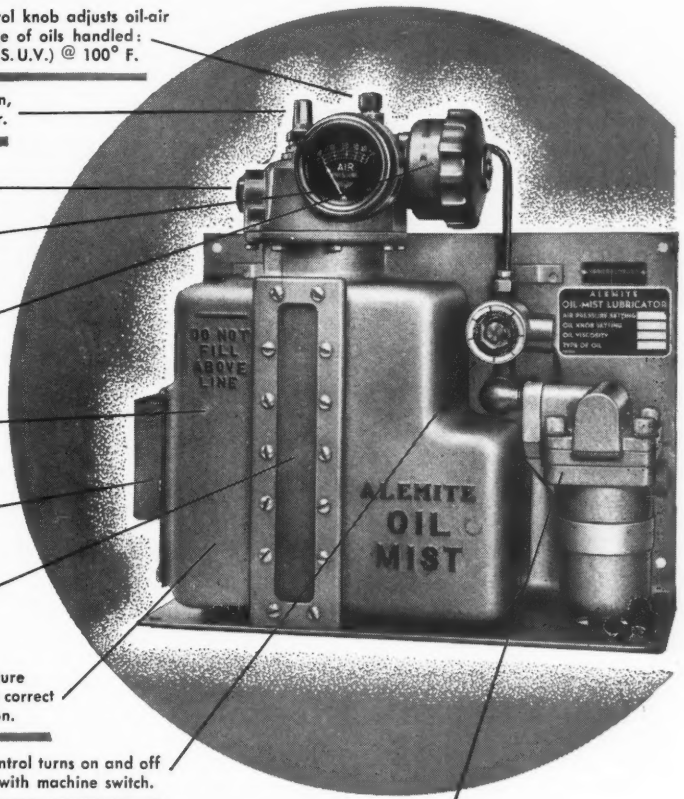
BEL-RAY Company Inc.
MADISON, NEW JERSEY

You asked for it! Designers told us what industry had to have!

ALEMITE OIL-MIST

Proved in countless applications – multiplies bearing life – slashes product spoilage – boosts machine output!

Hundreds of case histories prove savings, ease of installation, increased output with Oil-Mist. And Oil-Mist is simple to design into any machine. Oil-Mist applies a constant, clean, cool film of oil uniformly to working parts – vees, chains, slides, gears, all types of bearings. Replaces grease systems. No moving parts – operates on compressed air – completely automatic, fool-proof!



1. Oil flow control knob adjusts oil-air mixture. Range of oils handled: to 1,000 sec. (S.U.V.) @ 100° F.
2. Loader fitting for fast, clean, filtered refilling of reservoir.
3. Oil-Mist delivery outlet for main line leading to bearings.
4. Air gauge registers to 50 psi.
5. Air regulator—operating pressure 5 to 20 psi. Reduces pressures from up to 200 psi. Normal air consumption, .7 to 1.2 cfm.
6. Reservoir capacity one gallon. Also available in 12 oz. size.
7. Low level indicator switch turns on warning signal or stops the machine when oil level is low.
8. Nylon plastic window gives visible check of oil supply.
9. Heater for outdoor or low temperature applications. Thermostat keeps oil at correct temperature for efficient atomization.
10. Solenoid air control turns on and off simultaneously with machine switch.
11. Moisture separator and filter removes up to 98% of moisture from incoming air at flow rate up to 1 cfm.

Complete range of models and multiple unit models to fit any machine – any application

Three types of bearing fittings allow the use of OIL-MIST on any machine!

Oil-Mist fittings bring the most efficient lubrication in the world to any anti-friction bearing—roller, ball, needle.

Spray fittings are recommended for open and enclosed gears and chains. Allow for a concentrated spray of oil where needed.

Condensing fittings apply oil in liquid form to plain bearings, slides, ways, vees, cams and rollers.

Alemite Oil-Mist offers these lubrication advantages

Automatic lubrication • Continuous lubrication
Eliminates guesswork • Greater safety • Cuts oil consumption up to 90%
Extends bearing life • Stops oil drippage • Saves man-power
Reduces number of lubricants needed • Eliminates "Down-time"

FREE ... *write today!*

Use coupon below for your free copy of the Oil-Mist catalog and data book!

ALEMITE OIL-MIST LUBRICATION

A PRODUCT OF SW STEWART WARNER

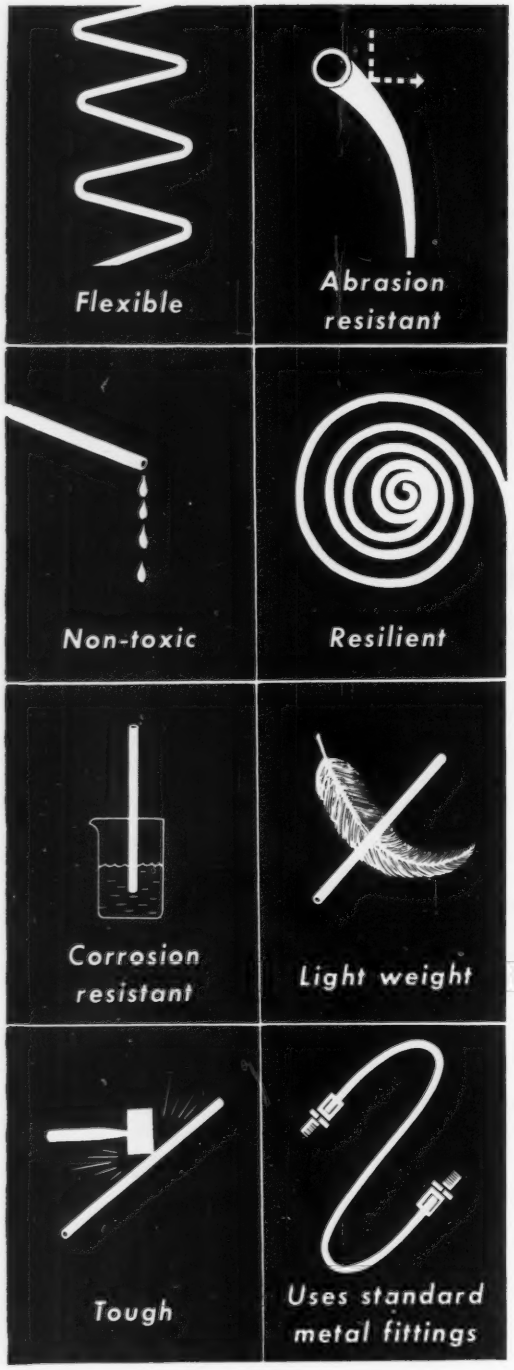
Alemite, Dept. T-125, 1850 Diversey Parkway, Chicago 14, Illinois

Name .....

Company .....

Address .....

City ..... State .....



New nylaflow* tubing is all these things ...and more!

NYLAFLOW . . . the new POLYPENCO® nylon tubing . . . now permits you to get all the advantages of nylon in pressure lines for lubricants, air, fuel and oil, coolants, process streams, and hydraulic fluids.

With all its superior performance, NYLAFLOW tubing costs less in some small sizes than copper tubing. And it costs much less than flexible rubber hose.

Another thing, NYLAFLOW costs less to install. There's no pre-bending . . . no intermediate fittings . . . no flexible hose attachments. Instead, NYLAFLOW can be run in continuous lengths and connected simply by using a standard metal compression or flare fitting at each end. Because it's flexible and light weight, NYLAFLOW tubing also simplifies prefabrication of tubing assemblies.

NYLAFLOW tubing is now available in stock diameters and lengths. There are two grades: Type T with a tested bursting strength of 1,000 psi; and Type H, 2,500 psi. The tubing also is available in colors for color coding.

SEND FOR NEW *NYLAFLOW* TUBING BULLETIN

THE POLYMER CORPORATION of Penna. • Reading, Penna.

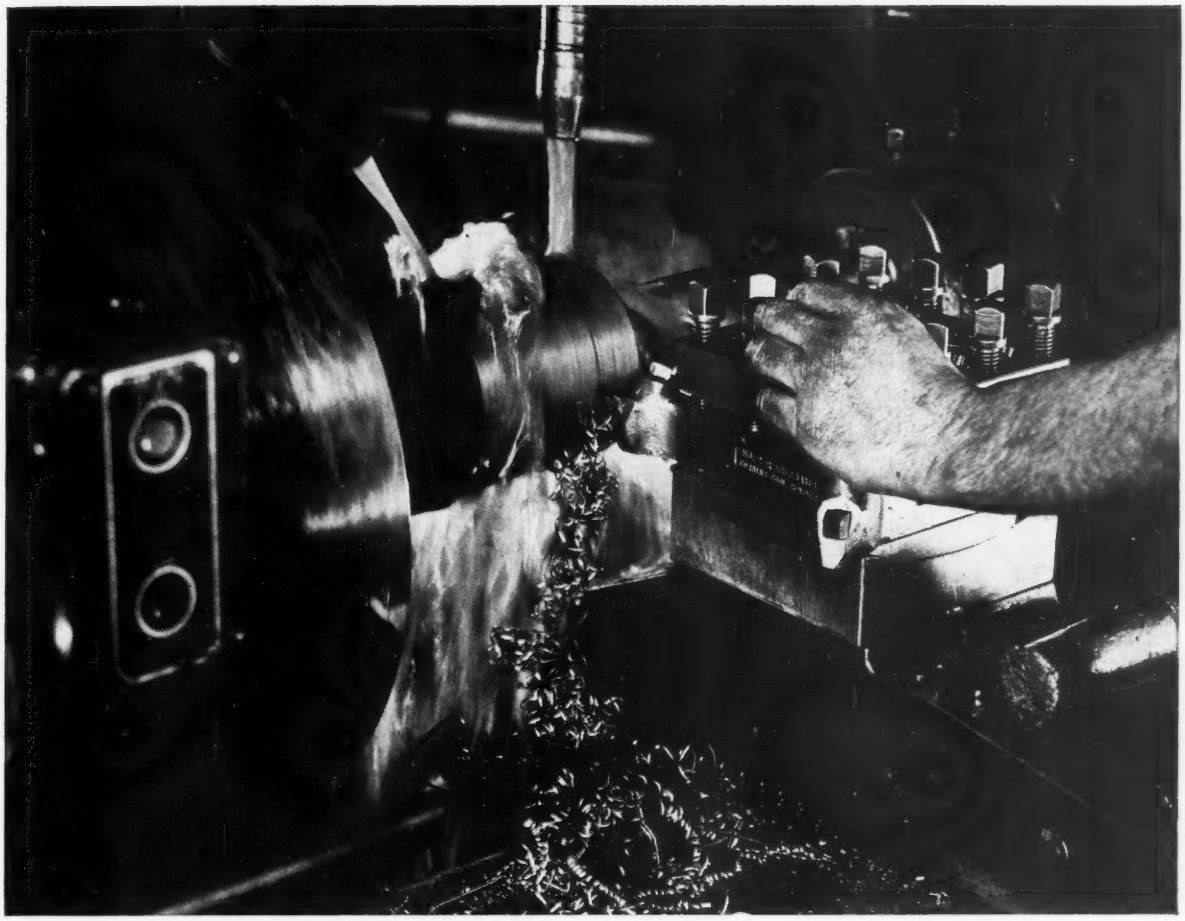
POLYMER *NYLAFLOW* TUBING

. . . nylon . . . Teflon† . . . and other non-metallic shapes

In CANADA: Polypenco, Inc., 2052 St. Catherine W., Montreal, P.Q.

†Teflon is the trademark for DuPont tetrafluoroethylene resin

*NYLAFLOW is the trademark for The Polymer Corporation's nylon tubing



LIQUID DRESINATE® EMULSIFIER IMPROVES HARD WATER STABILITY

Soluble cutting oils, especially those used in hard water areas, offer two advantages when made with liquid Dresinate. Blends of this Hercules emulsifier with petroleum sulfonate improve emulsion stability over a wide range of water conditions and concentrations, and, in most cases, cut compounding costs.

Economies in plant equipment and manpower needs are made possible through the use of a liquid Dresinate. These low viscosity, high solids emulsifiers are manufactured to exacting standards assuring product uniformity from shipment to shipment.

Liquid Dresinate, available in a number of different types, is described in a recent booklet. This booklet also contains suggested formulations and information regarding selection of the correct Dresinate for emulsion-type oils used in metal working and other fields. Write Hercules Powder Company for your copy.

Industrial Chemicals—PMC Dept.

HERCULES POWDER COMPANY

INCORPORATED

979 Market Street, Wilmington 99, Delaware

PT55-1

11th ASLE Annual Meeting & Exhibit

APRIL 4-5-6, 1956 **HOTEL WILLIAM PENN, PITTSBURGH**

Seventeen technical sessions, a panel discussion, and a five-session educational course have been tentatively scheduled as the Program for the 11th Annual Meeting & Lubrication Exhibit of the American Society of Lubrication Engineers to be held in Pittsburgh on April 4, 5 & 6, 1956.

The Panel will cover "Steel Mill Cold Rolling Lubricants."

Technical Sessions will be devoted to: (1) Disposal of Waste Lubricants and Coolants with Reference to Stream Pollution, (2) Effect of Environmental Factors on the Lubricant, (3) Fire Resistant Fluids Today, (4) Friction and Wear, (5) Fundamentals of Hydrodynamic Lubrication, (6) Gear Lubrication, (7) General Industries, (8) Lubrication Equipment, (9) Lubrication Fundamentals, (10) Metalworking Lubricants, (11) Plain Bearings, (12) Principles and Practices of Economic Lubrication, (13) Properties of Lubricants, (14) Railroad Journal Bearings, (15) Rolling Contact Bearings, and (16) Spray Applications of Lubricants. The tentative program, by session, and technical papers to be presented include:

1A, Spray Applications Of Lubricants. (Wed. a.m.)
- **The Spray & Dip Methods Of Applying Lubricants To Rope,** by D. B. Burroughs
- **Spray Lubrication Of Gear Oils To Roll Neck Bearings,** by C. Winn & J. S. Aarons

1B, General Industries. J. Hetchler, Chrmn.
- **Cutting Fluids,** by A. W. Ackerman & F. E. Anderson

1C, Fundamentals Of Hydrodynamic Lubrication.

2A, Steel Mill Cold Rolling Lubricants (Panel). (Wed. p.m.)

2B, Properties Of Lubricants.
- **Reduction Of Low Temperature Sludge Formation In Automotive Engines,** by R. I. Potter
- **The Dynamic Demulsibility Characteristics Of Oils,** by E. W. Brennan & R. G. Moyer

2C, Lubrication Fundamentals.
- **Surface Viscosity & Elasticity Of Lubricating Oils,** by D. W. Criddle
- **Flow Analysis Of Lubricants From Measurements With An Automatic Viscometer,** by Ruth N. Weltmann & P. W. Kuhns

2D, Education Session, I.

3A, Gear Lubrication. (Thurs. a.m.)

3B, Effect Of Environmental Factors On The Lubricant.
- **Effects Of High Temperatures On Lubricants,** by E. E. Klaus
- **Effect Of Aircraft Engine Operation On The Properties Of Synthetic Based Lubricants,** by T. Davidson & J. H. Way
- **The Effect Of Bacteria On Soluble Oil Emulsions,** by H. Pivnick, L. Sabina, R. S. Maharaja & K. Fotopoulis

3C, Railroad Journal Bearings. L. E. Hoyer, Chrmn.
- **Investigation Of Oil Additives For Boundary Lubrication Of Railroad Journal Bearings,** by A. Miller
- **Experimental Investigation On Railroad Journal Bearing Operation Characteristics,** by A. L. Busby & G. L. Tigman
- **Analysis Of Factors Influencing Railroad Bearing Operating Temperatures Under Service Conditions,** by W. M. Keller & G. L. Tigman

3D, Education Session, II.

4A, Plain Bearings. (Thurs. p.m.)
- **Theory Of Grease Lubricated Thrust Bearings,** by A. Slibar & P. R. Paslay

4B, Fire Resistant Fluids Today.
- **Fire Resistant Turbine Lubricants,** by J. J. O'Connor

4C, Metalworking Lubricants.
- **Heat Treatment Quenching Oils,** by L. W. Kalinowski & R. Weir
- **Grinding Fluids For Titanium,** by M. C. Shaw
- **Rolling Oils For Non-Ferrous Metals,** by S. Paraday

4D, Education Session, III.

5A, Rolling Contact Bearings. (Fri. a.m.)
- **Dynamic Oxidation Grease Tester,** by A. E. Baker

5B, Disposal Of Waste Lubricants & Coolants With Reference To Stream Pollution.

5C, Friction & Wear. E. M. Kipp, Chrmn.
- **Surface Film Thickness & Boundary Lubrication,** by I-Ming Feng
- **A Critical Temperature For Surface Damage in Sliding Metallic Contact,** by L. F. Coffin, Jr.
- **On A Criterion Of Cutting Velocity In Metal Machining,** by F. F. Ling & E. Saibel
- **Use Of Electron Diffraction In Lubrication Research,** by D. Godfrey

5D, Education Session, IV.

6A, Friction & Wear. (Fri. p.m.)

6B, Lubricant Equipment.
- **Crane Maintenance Program,** by W. H. Morgan
- **Lubrication Problems In Taconite Processing,** by F. Darner

6C, Principles & Practices Of Economic Lubrication.

6D, Education Session, V.

D. W. Sawyer, Program Chairman

Adapting The Static Water Drop Test To Research Methods

by E. J. Schwoegler & L. U. Berman*

The Static Water Drop Test which is presently used as a qualifying test for the purchase of service material can be used as a research tool if the specimen preparation is modified. This paper presents in detail the method of preparing specimens so that a shorter test period of 48 hours can be used with duplicate samples. The test results are quite precise and accurate. More rapid tests are thus possible so that a large number of polar organic compounds may be evaluated in the search for optimum corrosion inhibition.

Recently a new corrosion test was described by H. R. Baker, D. T. Jones, and W. A. Zisman[1] of the Naval Research Laboratories. It is known as the Static Water Drop Test, and it is stated by the authors to overcome many of the disadvantages of the well known ASTM turbine oil test. The method has been found to be quite effective as a qualifying test in specifications for the purchase of military material, and it appears in Federal Specifications VV-L-791e as Procedure 5311. Usually four specimens are used; three must show no corrosion during the test period, usually 168 hours, at 140 F. In this application the test is essentially a go—no-go test method.

In these laboratories it became necessary to evaluate several hundred polar organic compounds as corrosion inhibitors in a research project in which the configurational and functional group effects were to be noted in two different oils. The evaluation method selected for this investigation had to be: (1) An effective screening procedure, (2) Sufficiently precise and accurate over a short test period.

With the exception of the long test period required, the static water drop test seemed to be ideal for the study described. To determine whether a shorter test period with only two specimens instead of four would be satisfactory, the static water drop test was used to evaluate a number of compounds in two different oils. In order to determine also whether differences in operator techniques had influence on the test results during a 48-hour test period, two operators used a procedure similar to that described in VV-L-791e. The results of this study are given in Table I.

The results in both oils show not only differences between tests of the two operators but also differences between duplicate samples of the same operator. These differences are more pronounced in the petroleum base oil than in the diester base oil.

*Armour Research Foundation, Illinois Institute of Technology, Chicago 16, Ill.

(This paper was presented at the ASLE 9th Annual Meeting, Cincinnati, April 7, 1954.)

If the tests had been allowed to proceed for a total of 168 hours the differences noted would be reduced and the effective compounds would be obvious. While the longer test period and the use of four test specimens instead of two enhance the effectiveness of this test for qualifying purposes, these same factors reduce the effectiveness of the test as a research method in the development of better inhibitors.

In spite of the differences in the 48-hour test period the results were sufficiently promising to warrant further study of this method. Since the only surface treatment given the test specimen prior to use was some rubbing of the dimpled test area with 5/0 sandpaper, it was thought that the differences noted could be eliminated by a controlled polishing sequence. The polishing sequence decided upon was to polish the specimen before the forming operation rather than after it. This sequence produced a more uniform test area.

The work described in this paper presents in detail a specimen preparation technique which minimizes the differences noted in the above evaluations and allows the static water drop test to be advantageously used over a 48-hour test period as a research tool.

EXPERIMENTAL. General Considerations. In determining the preparational sequence, consideration was given to the important factors necessary for satisfactory specimen preparation. The factors considered were those related to the metal and methods of surface preparation:

A. Steel. (1) Steel specifications; (2) Flatness of specimen; (3) Extraneous scratching; (4) Rolling marks.

B. Surface Preparation. (1) Grinding methods; (a) Abrasive papers vs powders; (2) Polishing methods; (a) Wet vs dry polish; (3) Surface finish.

Steel. As described by Baker, et al., the method calls for the use of an SAE 1020 specification cold rolled steel specimen 1/32 inch in thickness. Strips are available in a width of 1.625 inches, and the triangular pieces are cut from them. To insure the flatness of the piece for the grinding and polishing operations the pieces are cut on a special die also described by the authors. The strip stock should be free of gouges and scratches as these are difficult to remove during the grinding and polishing operations.

The cold-rolled steel surface has a grain-like appearance, the individual marks being short hair-like lines. These are probably due to the rolling operation and can be referred to as rolling marks. Most

of these are not hair-line scratches, but are small openings in the steel which have been partially closed during rolling. Grinding opens these further and causes a larger scratch to appear. By careful grinding and polishing, these rolling marks can be removed. Removal of these marks is very important as these openings can occlude materials which either cause or inhibit corrosion to give rise to significant differences when a short test period is used.

Surface Preparation. The surface finish of a metal specimen to be used in corrosion studies must be uniform and free from scratches and foreign matter.

By selecting the proper grit size and using smaller sized grits as the polishing proceeds, a uniform surface finish is obtained. The type of grit is said to influence to some extent the corrosion of the metal surface. Emery has been known to accelerate certain types of corrosion, and recently there is some evidence[2] to indicate that silicon carbide particles have a tendency to set up galvanic cells on metal surfaces. Both have been used in this study with equal effectiveness but silicon carbide has been selected as suitable for these grinding and polishing operations because its extensive use in these laboratories has been satisfactory. There is a greater tendency for these grits to remain if the surface is nonuniform and contains pits, etc. None of the corrosive effects reported were observed when these particles were removed by an effective cleaning sequence.

Abrasive powders have been recommended over abrasive papers, but, if care is taken to avoid high temperatures during polishing and if an efficient cleaning sequence is used, abrasive papers are quite satisfactory for polishing and grinding and the resin binders do not seem to cause difficulty. Abrasive papers were used in this study.

The final polishing of the specimen prior to use in the test to give the active surface can be either wet or dry. In this study the wet polish technique with water was selected. Corrosion after this polish is also prevented by using an effective cleaning and drying procedure.

PREPARATION OF SPECIMEN. Fig. 1 shows a flat triangular piece cut from strip stock. The detail of the rolling marks are evident, and their regularity and linear aspects are visible. Random scratches show up more clearly than rolling marks because of the pronounced effect of light on the scratches.

Two procedures have been used to prepare these metal specimens for the static water drop test for use in research. The laboratory method will be described completely since the details can be described best in these operations. The procedure utilizing commercial grinding and polishing sources will be described only as a modification of the laboratory procedure. Since the cleaning and drying operations used in specimen preparation also are critical they will be described in detail in their proper place in the preparation sequence.

Laboratory Method. The triangular piece (plate) is degreased by holding it in a pair of tweezers and sweeping it through trichloroethylene or other suitable degreasing solvent at 60-70 C., until oil and grease are removed.

Trichloroethylene is viewed by some workers as

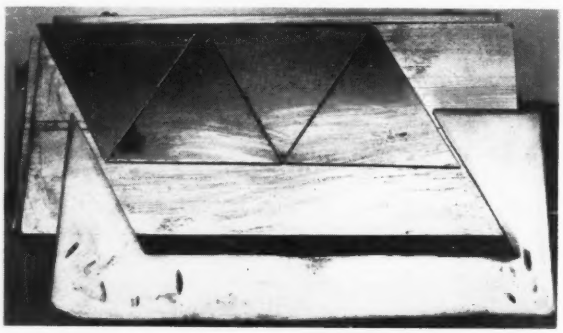


Fig. 2. Magnetic chuck with specimens.

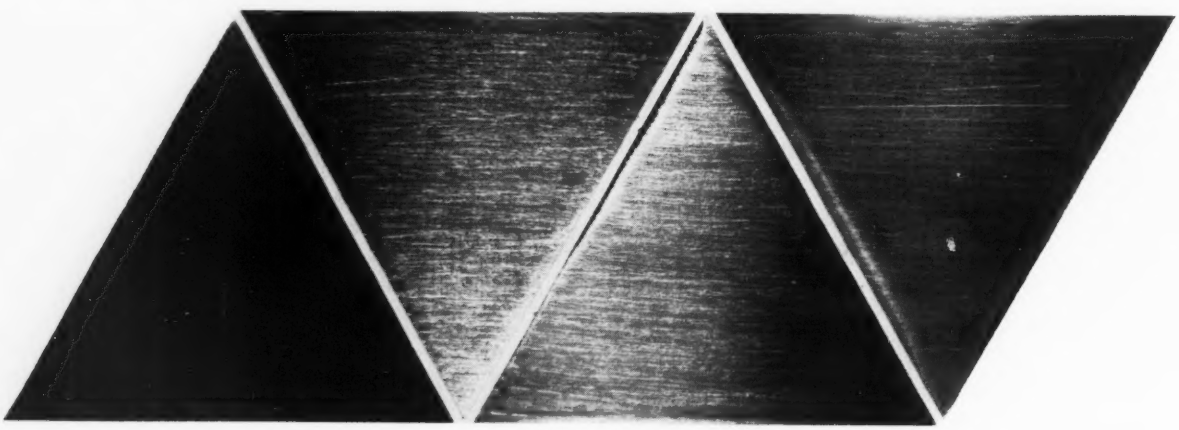


Fig. 1. (left) Triangular specimen stock.

Fig. 3. (second from left) Specimen surface after No. 1 emery polish.

Fig. 4. (second from right) Specimen surface after dry No. 500 silicon carbide polish.

Fig. 5. (right) Specimen surface after dry No. 600 silicon carbide polish.

Table I. Static Water Drop Test Results (Procedure 5311-VV-L-7912, 0.2% solution). Key: *Rating is based on area covered by drop. 10 represents 100% covered with rust.

Compound	Base Oil	Corrosion Rating*							
		Petroleum				Diester			
	Operator	1		2		1		2	
		24 hr	48 hr	24 hr	48 hr	24 hr	48 hr	24 hr	48 hr
2,4,6-Tri-(dimethylaminomethyl)phenol		1	1	0	0	0	0	0	0
		5	5	2	2	0	0	1	1
Synthetic petroleum sodium sulfonate		1	1	2	2	1	1	0.25	0.25
		2	2	2	2	0	0	0.25	0.5
Pentaerythritol monooleate		0	0	0	2	10	10	10	10
		0	0	0	2	10	10	10	10
N-Aminoethylmorpholine		0	0	0	0.5	0	0	0	0
		0	0	0.66	0.5	0	0	0.25	0.5
Eicosane sulfonamide		2	2	1	2	1	1	1	1
		1	2	2	2	1	2	1	2
Dinonylamine		8	9	0	0	0	0	0	0
		0	0	7	8	0	0	0	0
Benzyldimethylamine		7	9	10	10	0	0	0	0.5
		10	10	10	10	1	1	0	0
Sodium dibutyldithiocarbamate		0.5	0.5	0	0.5	1	9	1	2
		2	4	5	5	9	10	1	2
Triethanolamine soap of tall oil		6	6	8	8	0	0	0	0
		8	8	7	7	0	0	0	0
Barium alkyl aryl sulfonate		0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0
N-Aminopropylmorpholine		0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0
Triethylenetetramine		8	10	10	10	0	0	9	10
		10	10	10	10	0	0	10	10
Quinoline		10	10	10	10	10	10	10	10
		10	10	10	10	10	10	10	10
Trihexyl phosphite		7	10	10	10	10	10	10	10
			10	8	9	1	-	10	10

deleterious in a corrosion laboratory. However, using it to degrease specimens initially is not harmful since the grinding and polishing operations following degreasing removes any harmful by-products. Degreasing several pieces at a time by movement in the liquid is not recommended since degreasing is not complete in many instances and scratching of the specimen also occurs. If a large number of specimens is to be degreased, vapor degreasing is recommended.

An electric vibration sander or any other suitable sander is used for the first grinding-polishing operations. Commercial abrasive papers 4 inches wide are available for use with this sander.

A magnetic chuck was found to be very effective for holding the specimens for grinding or polishing. Four specimens can be held conveniently in position and polished at one time on the chuck used in these laboratories. Fig. 2 shows the four specimens on the chuck. To protect the uncovered face of the chuck from the abrasive, a metal template is cut to cover the chuck area not covered by the specimens.

The specimens are arranged on the chuck so that the rolling marks are perpendicular to the length of the chuck. The polishing is carried out perpendicular to the rolling marks—that is, along the length of the chuck.

Dry-Polish. The plates are first dry-polished alternatively with No. 280 silicon carbide paper and No. 1 emery paper, ending with the emery paper, until the rolling marks are removed. The presence of rolling marks is observed by sighting across the plates held at a 45-degree angle. Fig. 3 shows a specimen after this first grinding-polishing operation.

This operation is followed by another dry polish using No. 500 silicon carbide paper until a smooth finish is obtained. This polishing operation preferably is made perpendicular to the abrasion marks from the first grinding operation. This must be followed by another dry polish with No. 600 silicon carbide paper. Should difficulty be encountered between the first grinding-polishing operation and the No. 500 silicon carbide, an intermediate grind with No. 400 silicon carbide can be used to remove those abrasions difficult to remove with the No. 500 paper. Fig. 4 shows the specimens after polishing with No. 500 silicon carbide paper, and Fig. 5 after polishing with No. 600 silicon carbide paper. By rotating the specimen, either a satin finish which is shown or a mirror-reflecting finish can be observed, and assists in observing imperfections.

After this series of dry polishes, metal particles

and abrasive powders are wiped gently from the specimen with cleansing tissue. If the specimen is not to be wet-polished immediately, it can be stored at this point in water-free benzene until it is ready for the wet-polish operation. Care must be exercised in storing these specimens to avoid scratching. A convenient method of storage is to pile the specimens in the jar so that the polished surfaces of two specimens are in contact.

After removal from benzene storage, the following solvent treatment is used prior to the wet-polish operation: (1) The specimen is removed from benzene storage with tweezers and swept through methanol at room temperature to remove the benzene completely; (2) Finally it is swept through distilled water at room temperature to remove the methanol. If the specimens are not stored after the dry-polishing operation but are wet-polished immediately for use, the solvent wash is omitted.

Wet-polishing is a hand operation. A flat surface is needed and a plate glass surface has been found to be satisfactory. The final polish is carried out with No. 600 silicon carbide paper. The paper is placed on the glass, and the abrading surface is wet with water. The specimen is polished by rubbing it back and forth across the paper in a straight line perpendicular to previous polish lines until a uniform satin finish is obtained. Rubber finger tips may be used to prevent the fingers from slipping from the specimen during polishing.

The center of the specimen is most important since this is the test area. The satin finish must be uniform in this area. If dry-polishing has not been complete, scratches which are difficult to remove by wet-polishing will be seen. Uniformity is best observed by tilting the specimen at a 45-degree angle to a light source. Fig. 6 shows an incompletely wet-polished specimen which indicates the non-uniformity. Fig. 7 shows a satisfactory specimen with uniform satin finish.

The polished specimen is washed and cleaned to remove particles, moisture, etc., which can cause corrosion. The following sequence is recommended:

(1) The specimen held with tweezers is swept through distilled water to remove grits and metal particles.

(2) The specimen is swept through methanol to remove water and any occluded material not removed by water.

(3) Step 2 is repeated with benzene (preferably a water-free, water-white nitration grade).

(4) After washing, the specimen is wiped clean with cleansing tissue to remove any foreign matter still present, and any adhering lint is removed with a blast of air from an ear syringe.

(5) Cleaned specimens are stored under fresh nitration grade benzene (mentioned above) in a capped jar until ready for forming (not longer than 48 hours).

Step 4 is important since any minute particles remaining are known to start corrosion cells even during storage in the benzene.

COMMERCIAL POLISHING OF SPECIMEN. The dry-polishing of specimens has been carried out also in a commercial grinding shop. The initial grind was made with a No. 240 silicon carbide cloth on a belt grinder. The specimen was held on a magnet, modified to prevent the specimen from slipping, and the grind was made perpendicular to the rolling marks. After another polish with No. 400 silicon carbide cloth, the specimen was buffed to a mirror-like finish. The final wet-polish with No. 600 silicon carbide paper was carried out in the laboratory. Corrosion test results were the same for both laboratory and commercially prepared specimens.

Certain precautions must be observed when specimens are polished commercially. These are:

(1) The initial grind should be even with not too much removed from one spot.

(2) The specimen holder should provide a flat surface so that pressure against the belt does not cause uneven removal of metal.

(3) Grinding and polishing must be controlled so that the specimen is not bent, burned, or over-

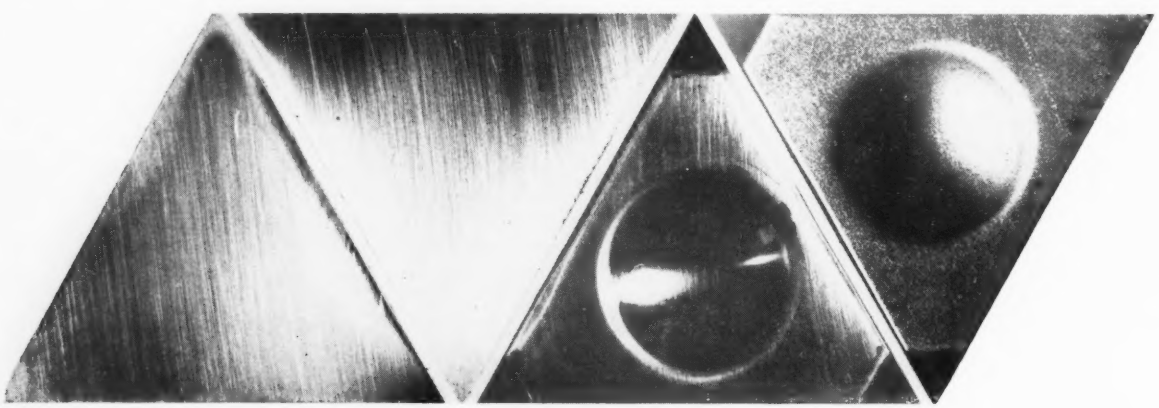


Fig. 6. (left) Incompletely polished specimen.

Fig. 7. (second from left) Specimen surface after final wet polish with No. 600 silicon carbide.

Fig. 8. Formed finished specimen; (Fig. 8a, second from right) Prepared by Laboratory method; (Fig. 8b, right) Commercially available.

Table II. Corrosion Inhibiting Properties of Some Polar Compounds (2% concentration). Key: G — good; F — fair; I — ineffective.

Compound \ Base Oil	Corrosion Results							
	Petroleum				Diester			
	Rating			Classification	Rating			Classification
	1 hr	24 hr	48 hr		1 hr	24 hr	48 hr	
N-Aminoethylmorpholine	1	1	1	G	0.1	0.1	0.1	G
	1	1	1		0.1	0.1	0.1	
Dinonylamine	8	10	-	I	0	0	0	G
	8	10	-		0	0	0	
Benzyldimethylamine	8	8	-	I	0	0	0	G
	8	8	-		0.05	0.1	0.1	
Triethylenetetramine	0	0	0	G	1	1	1	F
	0	0	0		1	1	1	
Quinoline	9	9	-	I	9	10	-	I
	9	9	-		9	10	-	
Pentaerythritol monooleate	0	0	0	G	5	10	-	I
	0	0	0		5	10	-	
Trihexyl phosphite	9	10	-	I	8	10	-	I
	9	10	-		8	10	-	
Triethanolamine salt of tall oil	0	0	0	G	0	0	0	G
	0	0	0		0	0	0	
Eicosane sulfonamide	0	1	1	F	3	10	10	I
	0	1	1		3	10	10	
Synthetic sodium petroleum sulfonate	1	9	9	I	0	0	0	G
	1	9	9		0.05	0.05	0.05	
Sodium dibutyldithiocarbamate	3	7	7	I	0	10	-	I
	3	7	7		0	10	-	
2,4,6-Tri-(dimethylaminomethyl)phenol	1	1	1	F	0	0	0	G
	1	1	1		0	0	0	
Barium alkyl aryl sulfonate		0	0	G	-	7	9	I
		0	0		-	7	9	
N-Aminopropylmorpholine		0	0	G	-	0	0	G
		0	0		-	0	0	

heated.

(4) Polished specimens should be wrapped individually after polishing to protect them against moisture, abrasion, etc.

Formed specimens are available commercially for use in the qualifying tests over the 168-hour test period, but these are not recommended for research evaluations over the shorter test period of 48 hours. Fig. 8 shows a specimen prepared according to the procedure herein described and a commercial specimen.

PRESS FORMING OF SPECIMEN. The specimen is formed in a hydraulic press with the dies and procedure described by Baker, et al. The polished specimen is removed from benzene storage and wiped with clean surgical gauze. The specimen held by the edge with tweezers is placed in the die. A pressure between 3000 to 4000 psig is applied. Once the desired pressure has been found, the same pressure should be used on all specimens so that each specimen will have the same degree of stress and cold working. The corners of the specimen are turned down so that the specimen stands level. A specimen formed in the manner described is shown in Fig. 8. Formed specimens can be placed again in benzene but not for longer than 48 hours. Over longer periods even in benzene there is a tendency to form an oxide film which interferes with the test.

EVALUATION PROCEDURE. Before use in the tests, the specimen is given the following treatments:

(1) On removal from benzene storage, for 30-40 seconds it is swept through hot mineral solvent (flash point, 105 F.) held just below the boiling point.

(2) Then for a similar period of time it is swept through anhydrous methanol held just below the boiling point, removed, and air-dried. (Any contaminants can be removed from the specimen by wiping it lightly with surgical gauze, and blowing off any adhering lint with a blast of air from an ear syringe).

(3) Specimens (plates) thus treated are stored with polished surfaces in contact in a desiccator over Drierite until ready for use. (Not longer than 48 hr.)

Test units are set up and read as described by Baker, et al. The specimen is placed in a clean, dry 100-ml. beaker (other containers such as a Petri dish or a crystallizing dish may be used) so that the turned down corners of the specimen rest on the bottom. Oil containing the material to be evaluated as the inhibitor is added to the beaker so that the oil level is 3-5 mm. above the top of the specimen.

Usually a 0.2% solution of the compound in oil is used, although solutions of other concentrations can also be tested. This test unit is covered with a clean, dry watch glass and placed in an oven held at 140 ± 1 F., for a one-hour period. The unit is removed and 0.2 ml. of distilled water is introduced into the recessed portion of the specimen by means of a 1-ml. hypodermic syringe fitted with a No. 27 needle. Care must be taken to prevent the needle from touching the specimen as this may cause a break in any film of polar compound adsorbed on the metal surface. The distilled water is boiled and allowed to cool before use. If a large number of tests are to be run, sufficient distilled water can be prepared and stored in a glass stoppered bottle until needed.

The test unit is placed in the oven again and observations for corrosion are made at convenient intervals such as at 1, 6, 8, 12, 24, and 48 hours.

Reading Static Water Drop Corrosion Tests. In the static water drop test the area of corrosion is used as the measurement. The area occupied by the water droplet constitutes the total area for evaluation purposes. The portion of that area corroded is noted on a 0-10 scale with 10 being 100% of the area corroded. Areas below 10%, i.e., 1—, are read in fractions.

To assist in reading test results, a standard inhibitor can be used for comparison. This should be a stable, homogeneous compound with mild corrosion-inhibiting properties. This standard will serve also as an aid in determining difference in environmental conditions that may occur during testing.

For classification purposes it may be desirable to select ranges of corrosion inhibition arbitrarily and designate these as good, fair, and ineffective. While some overlapping is experienced, the results achieved are such as to make such a classification worthwhile, especially if large numbers of materials are to be evaluated. One such system used in this laboratory with a 0.2% concentration of a polar compound is as follows:

Good inhibitor — area of corrosion less than 1.

Fair inhibitor — area of corrosion between 1 and 3.

Ineffective inhibitor — area of corrosion greater than 3.

To reduce the borderline cases to a minimum, the volume of corrosion product could be considered along with the area of corrosion, and the results classified in that manner.

Figs. 9, 10 & 11 show results which are classified as good, fair, and ineffective inhibition, respectively. Excellent reproducibility was obtained on duplicate samples; the duplicates are not shown in the figures.

Table II gives the results of the evaluation of several compounds in a petroleum base lubricating oil and in a synthetic-base oil with the specimens prepared as described herein over a 48-hour test period. The results show that the difference encountered when specimens were prepared by a method similar to that described in VV-L-791e have been eliminated. Thus, by a controlled preparation of the test specimens it has been possible to obtain conclusive results with excellent duplication in a relatively short period of time. Specimen preparation has been carefully described so that it should be possible for different laboratories and operators to duplicate the results described here.

Other observations that can be made during this test usually have more significance in research than in qualification, so they are mentioned here: (1) The color of the corrosion product; (2) Corrosion outside the drop area; (3) Pitting corrosion; (4) Emulsion formation; (5) Surface and interfacial tension changes; (6) Formation of solids other than corrosion products. These same observations could be made in the qualification test (VV-L-791e).

These observations enable the investigator to obtain such information as the oxygen absorbing power of the system, or whether the polar compounds evaluated are emulsion formers or affect the interfacial tension, etc.

Fig. 12 demonstrates differences in surface tension as indicated by radii of drops, while Fig. 13 shows emulsion formation. Figs. 14 & 15 show red and black corrosion products, respectively. Fig. 16 shows the appearance of the test specimen after the corrosion products have been wiped from an ineffective inhibition sample.

DISCUSSION. The static water drop test can be used conveniently as a research tool over shorter test periods than is required for the qualifying tests. This is accomplished by using specimens which have been polished to a greater extent than those used in the qualification tests. This allows a large number of compounds and mixtures to be evaluated in a short period of time and only two specimens are used for this test. The precision and accuracy is such that differences can be noted between polar compounds; this makes the method valuable in such studies as configurational investigation of these polar organic compounds.

SUMMARY. The details presented are for a controlled specimen preparation method which results in consistent test data with only duplicate samples for a relatively short test period. The differences noted in the test results with specimens prepared in a manner similar to that described in Procedure 531.1 of Federal Specifications VV-L-791e were eliminated by using specimens prepared

Fig. 9. (1st row, left) Effective inhibition.

Fig. 10. (1st row, center) Fair inhibition.

Fig. 11. (1st row, right) Ineffective inhibition.

Fig. 12. (2nd row, left) Test unit showing emulsion forming type additive.

Figs. 13a & 13b. (2nd row, center & right) Test units showing additives with different surface tension properties.

Fig. 14. (3rd row, left) Red corrosion products.

Fig. 15. (3rd row, center) Black corrosion products.

Fig. 16. (3rd row, right) Test specimen after wiping corrosion products from ineffective inhibition sample.

as described in this paper.

Thus, excellent duplication with fairly accurate data is obtained in a short period of time with fewer specimens. These modifications make it feasible to use the Static Water Drop Test method for extensive surveys of polar organic compounds and combinations of these as corrosion inhibitors.

BIBLIOGRAPHY

(1) H. R. Baker, D. T. Jones & W. A. Zisman. Ind. Eng. Chem. 41, 1949, p. 137.
(2) Private Communication from Wright Air Development Center.

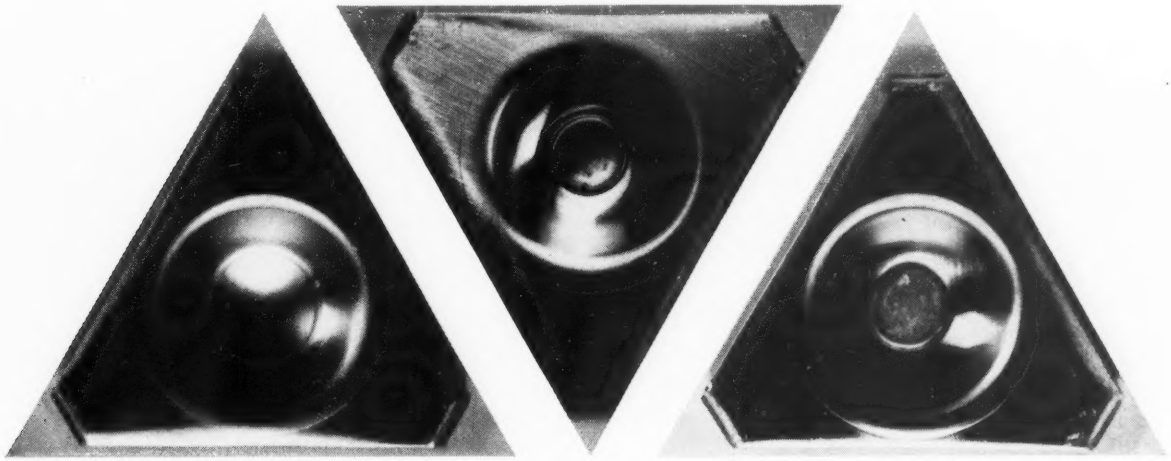


Fig. 9 Fig. 10 Fig. 11

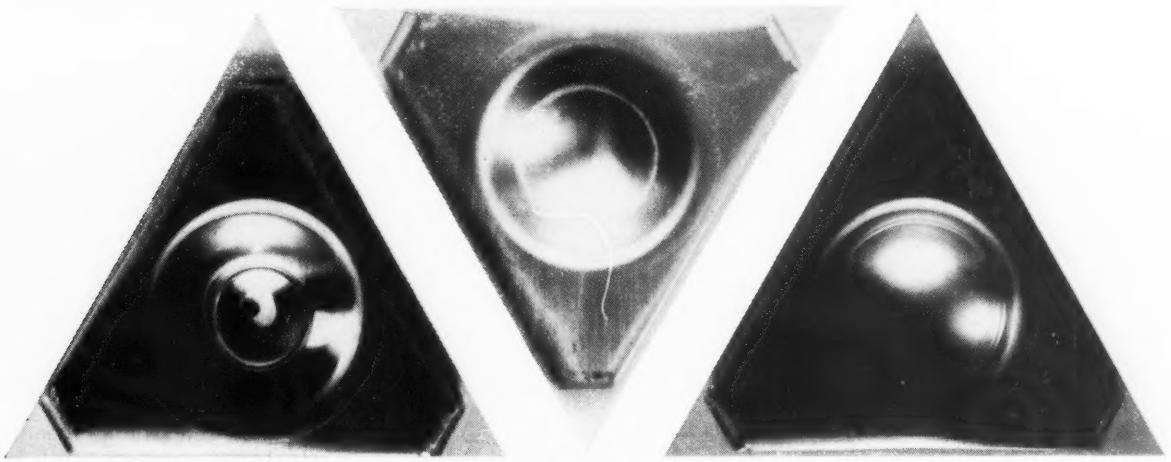


Fig. 12 Fig. 13a Fig. 13b

Fig. 14 Fig. 15 Fig. 16

ACKNOWLEDGEMENT. This paper is part of the work performed on Wright Air Development Center, Armour Research Foundation Project No. C 012-2. The authors wish to acknowledge the cooperation of J. C. Mosteller, J. Teres, R. J. Filler, and Major L. E. Michael of Wright Air Development Center, and the photographic work of N. W. Rodelius of the Foundation.

Board Actions

At the ASLE Executive Committee Meeting, June 17, 1953, it was agreed that the Actions of the Board of Directors should be published in the Society's journal. The Acts & Resolutions of general interest for calendar years 1954 & 1955 are herewith recorded as directed.

Resolution, 1-19-54. Resolved, that the Board of Directors hereby prescribes that annual re-election of the Administrative Secretary to the office of Assistant Secretary & Assistant Treasurer be automatic, without need for annual re-nomination and annual vote, until such time as changing conditions may warrant the repeal of this resolution.

Act, 1-19-54. Motion was made and passed that the 1956 Annual Meeting & Exhibit be held at the William Penn Hotel in Pittsburgh, Pa.

Act, 1-19-54. Motion was made and passed that Line 5 of Article V, Section 1, of the By-Laws be amended as follows: delete "March 15 to May 15" and substitute "February 1 to June 30."

Act, 6-25-54. Motion was made and passed that ASLE invite the ASME Activity Committee to participate in a Joint Conference to be held in Indianapolis, September 12, 13 & 14, 1955.

Act, 6-25-54. Motion was made and passed that the Executive Committee and the Handbook Advisory Committee promptly develop with McGraw-Hill a proposal for publication of the Lubrication Engineering Handbook and report at the next Board meeting.

Act, 10-20-54. Motion was made and passed that the Handbook Advisory Committee be instructed to proceed with tentative negotiations for publishing a Lubrication Engineering Handbook with the McGraw-Hill Publishing Co. A contract should be prepared and all transactions should be subject to the approval of the Board of Directors of ASLE. This report and contract proposal should be submitted by January 1, 1955, so that the Board may study it before the January Board meeting.

Act, 1-26-55. Motion was made and passed that ASLE join ASME in a joint conference on lubrication to be held in the Chalfonte-Haddon Hall, Atlantic City, N. J., October 8, 9 & 10, 1956.

Resolution, 1-26-55. Resolved, that the Board of Directors of ASLE agree to cooperate with the McGraw-Hill Book Company and its responsible contractors in the publication of a Handbook of Lubrication Engineering.

Act, 1-26-55. Motion was made and passed that the office of Secretary be reactivated.

Act, 1-26-55. Motion was made and passed that: Pursuant to Article IX, Section 11, Paragraph B (of the By-Laws) the Chairman of the Nominations Committee be empowered to notify prospective nominees of the allocation of a sum not in excess of $100 per year for a Director and for the Chairman of the Presidential Council; not in excess of $400 for the Vice-President at Large, and not in excess of $1,200 for the President, for expenses incurred on Society business, when the officer's company will not assume these costs; the total sum to be limited to $1,300 in any calendar year.

Resolution, 4-12-55. Whereas the Journal of the Society is its primary link of communication with the technical field, and whereas maintenance of a journal of the highest possible quality is essential to the Society's growth, be it resolved, that the Society strive to publish the foremost journal in the field of lubrication engineering by (1) Efficiently and impartially covering all phases of lubrication engineering as employed in the broadest interpretation of the term; (2) Matching the editorial and typographical quality of the best publications in this or in similar fields; (3) Prompt publication; (4) Incorporating suitable reader service. Be it further resolved, that any additional funds required to implement this policy be made available and that the editor be empowered to secure additional assistance in the preparation of copy for the printer and that a minimum of $1,500 per year be set for this service. Be it further resolved, that reasonable travel expense required by the assistant to set up proper liaison with the printer be made available.

Act, 4-12-55. Following recommendations of the Executive Committee, the Board established a new committee to be identified as "The Organization & Operations Committee" to study the Society structure and submit recommendations to cover, among other things (1) More efficiency in organization, better delineation of responsibility, better liaison; (2) More efficient use of manpower, more activity on part of membership as a whole; (3) More effective means of stimulating new projects, sponsoring research projects, making surveys, establishing records.

Act, 4-15-55. Motion was made and passed that a statement be prepared incorporating a comparison of the attendance at all our previous annual meetings including educational courses for further study of the problem so that we can take appropriate measures to have attendance at the annual meeting coincide with our growth in membership.

Act, 6-2-55. Motion was made and passed that the By-Laws Committee consider establishment of a membership grade of "Fellow" for retiring members after long Society membership. Such a membership grade would carry full membership privileges but no dues would be involved.

Book Reviews

Manufacture & Application Of Lubricating Greases, by C. J. Boner; Reinhold Publishing Co., New York, 1954, 977 pages, price $18.50. (Reviewed by K. H. Strauss, The Texas Co.)

Years have passed since an extensive book on lubrication greases has been published. The author has now come forth with a very comprehensive, up-to-date compilation of information on the manufacture, composition, and application of lubricating greases. The book contains relatively little subject matter of a drastically new nature. Its value lies in the gathering and sifting job done by the author to bring a tremendous amount of widely scattered pieces of knowledge into a coherent, readable framework. The entire field of lubricating greases is thoroughly covered, with primary emphasis on the practical rather than the theoretical aspects.

A rather long chapter covers the theory and structure of greases. However, by its very nature this chapter is more likely to be out of date sooner than the information in the remainder of the book. Here the author summarizes a great deal of work which, in most cases, only allows the presentation of the main ideas without detailed discussions of the merits of the various theories which are mentioned.

The next section of the book includes chapters on additives, raw materials, manufacturing processes, and equipment for lubrication of grease manufacture.

(Continued on p. 431)

Glass Lubricant In The Extrusion Of Steel

by J. Sejournet & J. Delcroix*

Molten glass is the lubricant in the Ugine-Sejournet process for extruding steel under conditions of high temperature and pressure where it facilitates the flow of the metal being deformed. This paper discusses the special conditions under which glass acts as a lubricant, and describes the very special requirements of this application and the responsive properties of glass in this use.

The idea of using glass as a lubricant may seem very strange at first glance. Glass is a very hard substance, brittle and abrasive, and thus apparently not well suited for use as a lubricant. However, glass in the molten state is the lubricant in the Ugine-Sejournet process under conditions of high temperature and pressure, and it facilitates the flow of the metal being deformed. It may, therefore, be advisable to examine first the special conditions under which glass acts as a lubricant so that the very special requirements of this application and the responsive properties of glass may become apparent.

(1) Description of the Extrusion Process. Extrusion is a process of forming materials (very frequently metals) by forcing a relatively large mass through a die of a desired shape in a suitable press. The material to be extruded is placed in a tubular shaped container, one end of which faces a die, and the other a ram or plunger. As the ram enters the container, the material is forced through the die and emerges as a bar of the form delineated by the die opening. The ram is actuated by hydraulic or mechanical pressure. Mechanical presses are generally used for small forces and long strokes, but for medium and large forces hydraulic presses are preferred owing to the smoothness of their operation and to their reliability.

There are basically two extrusion processes: the direct and the reverse process.

Direct extrusion is most generally employed. It is shown in Fig. 1. In this process the container and the die are fixed during the extrusion, and the ram or plunger is forced into the container to push the metal through the die.

With reverse extrusion the container is pushed around the die (see Fig. 2) which in this case is located at one end of the ram, and must travel the full length of the ram. The billet does not move in relation to the container, an arrangement which offers certain advantages from the point of view of friction as will become evident in the following. Here the extruded product must pass through the ram, limiting considerably the range of the process. In practice, the reverse extrusion process is rarely used and will not be considered in the following discussion.

At the end of the extrusion operation the assembly is essentially as shown in Fig. 3. The material left in the container is called the discard and should be kept at a minimum in order to improve the yield. After the extruded product is separated and the discard ejected, the press is ready for a new cycle of operations.

Tubes can be obtained in a similar way by placing a mandrel in front of the plunger. This tool pierces the billet lengthwise over a distance which is at least as long as the billet (see Fig. 4). After the billet has been pierced, further extrusion forces the product through the annular space of the die to generate a tube. In this case the mandrel and die are round and concentric and the usual round tube is produced. Tubes of a great variety of shapes (hexagonal, square, or oblong, or with fins) can be extruded just as well.

(2) History of Glass Lubrication. Lead has been extruded on presses since the beginning of the last century. As metallurgy progressed, other non-ferrous metals were formed by extrusion. At present aluminum and its alloys, brass, copper, and a great number of bronzes are being extruded. Among non-ferrous metals only certain bronzes and alloys of aluminum have not been extruded in commercial operations due to various major difficulties.

Metallurgists have always played with the idea of extruding steel in the same manner. However, in order to obtain industrially feasible conditions, the temperature of the billet has to be at least 1150 and up to 1300 C. (2100 and 2370 F., resp.). If the operation is carried out without any lubricant, the die is beyond the possibility of re-use, as shown in Fig. 5.

Fig. 5 shows two dies with the same profile; a new die and one which has extruded a single bar of steel without glass lubrication. This example illustrates the extreme difficulties of producing tools,

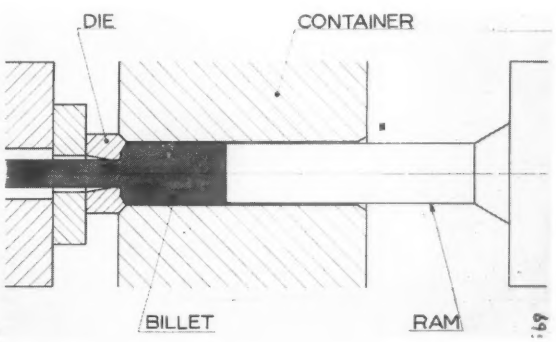


Fig. 1. Direct Extrusion.

*Comptoir d'Etirage, Paris, France.

(This paper was sponsored by the ASLE Technical Committee on Fluids for Metal Working, and presented at the ASLE 10th Annual Meeting, Chicago, April 15, 1955.)

especially dies, that can operate properly under these severe service conditions.

Many researchers have worked on this problem in the period between the two wars. Some have devoted their attention to special projects, such as the extrusion of thin and short tubes of special steels, e.g. stainless and Inconel. Nobody succeeded in extruding profiles.

Between 1930 and 1939 the Acieries Electriques d'Ugine, which had a certain background in the extrusion of light alloys, entertained the idea of forming steel by extrusion. The first approach to the problem was that of choosing a suitable steel to make better tools. A few analyses were available which were considered well fitted for the production of high heat-resisting dies.

Tests were performed in the extrusion department of the Comptoir d'Etirage in Paris which had a 660-ton press for the production of non-ferrous metal profiles. These tests indicated that it was possible to extrude steel, but the wear on the dies was prohibitive; the extrusion of profiles of steel again appeared to be an insuperable problem.

At this time one of the authors, then in charge of operations of the Comptoir d'Etirage, and Mr. L. Labataille, of the Tool Steel Sales Department of Ugine, became interested in this question and collaborated in a survey of the tests. Instead of using high-temperature resistant steels for the production of tools, they felt the difficulty might be overcome by reducing friction through studying the effect of lubrication more thoroughly. Successively different lubricants known in the forging art, i.e., graphite, talc, and borax, were studied.

Later on salts melting at high temperature, and then silicate, were reviewed. They noticed (about 1941) that there was one substance or class of substances which melted at a high temperature while retaining an adequate viscosity, so that it flowed under the combined effects of extrusion pressure and of adhesion to the metal. This substance also was found to be a particularly effective thermal insulating agent. It was glass. The joint efforts of the two companies, Ugine and Comptoir d'Etirage, and particularly of the two individuals who made these observations, ended in the filing of the first patents for the extrusion of steel based on the use of glass as lubricant. The basic idea had been found. It now had to be brought to the level of an industrial operation. Thus, the numerous problems posed by the daily conduct of such a process had to be solved fully to develop this idea.

Much time was needed to overcome all the obstacles, for the German occupation made it very difficult for French research workers to carry on with their work. In 1943 it was decided to build a new plant at the town of Persan, specially designed for the extrusion of steel and equipped with a 1650-ton press. The years of the war and of the post-war period retarded the realization of this project, and only in 1948 did the Paris plant stop and the Persan plant begin operations.

After this sidelight on the development of the idea of using glass as a lubricant, it may be helpful to review the theory of extrusion before discussing the effect of glass lubrication.

(3) Extrusion Formula. When a manometer records pressure in the principal hydraulic cylinder to measure the resistance encountered by a given billet during extrusion through a die, the pressure readings will show the force required in the extrusion of the billet. It will be found that:

1. Certain products are softer than others. At the same temperature, mild steel is easier to extrude than 18/8 stainless; all things being equal, the same soft steel extrudes more easily at 1200 C. (2190 F.) than at 1100 C. (2010 F.). Thus, the effect of resistance to deformation becomes apparent. It is a function of temperature, and can be determined for any given product quite readily.

2. In the same container the same steel heated to the same temperature is more easily deformed to a 30 millimeter round than to a 15 millimeter round. Thus, the effect of the extrusion ratio becomes apparent. This is the ratio of the cross-section of the billet under pressure and of the extruded bar, whether the products be solid or tubular in shape.

3. All other factors being equal, it is more difficult to extrude a billet 600 millimeters long than one of 300 millimeter length. The effort required to overcome the friction of the hot metal against the container is much greater in the first case than in the second.

With these conditions in mind the following extrusion formula will be readily understood. This formula was established theoretically and is currently used by the Comptoir d'Etirage, as expressed

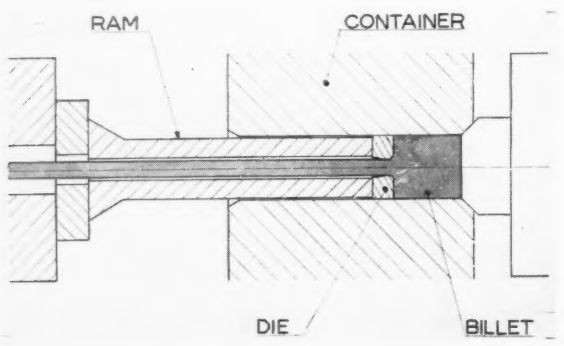


Fig. 2. Reverse Extrusion.

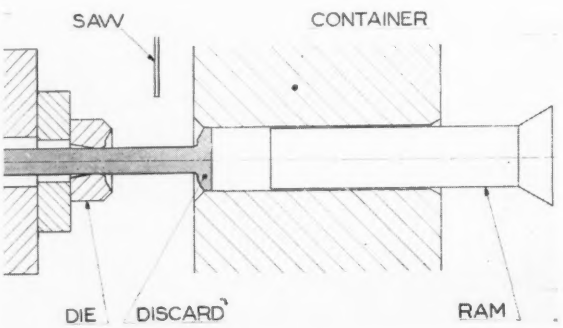


Fig. 3. Cut-off of discard.

for solid products:

$$p = \rho \log \delta e^{2fL/R}$$

In this formula p is the unit pressure in the container, i.e. the ratio of the force applied on the ram to the cross-section of the compressed billet; ρ is the resistance to deformation of the metal; δ is the extrusion ratio defined above; e is the base of natural logarithms; R is the radius of the bore of the container; L is the length of the billet under pressure; and f is the coefficient of friction of the hot metal against the container. In practice, the friction of the metal to be extruded against the die is built into the formula through the factor ρ.

It seems, besides, that this resistance due to friction against the die is relatively small compared with the other acting forces, the deformation of the metal being first and the friction against the container second in magnitude. However, the performance of the die is important for the process, and the number of good bars extruded through the same die varies widely depending on the lubricant used.

In other words, if there is no lubrication to reduce the friction between metal and container, the wear on the container will not increase materially; but a much more substantial force will be required for the extrusion, and will increase further in proportion to the length of the billet, until finally the press is blocked. However, even though the die is not lubricated, it is still possible to effect extrusion (provided that the billet be not too long). In difficult cases, such as the extrusion of steel, the die will be extruded together with the billet. After extruding a few meters of steel bar, the die will be completely deformed and will look as shown in Fig. 5.

In passing, a few numerical values of this formula are presented:

The extrusion pressure in the container ranges between 50 and 100 kg/mm² (75,000 to 150,000 lb. per sq. in.). The extrusion ratio can be between 5 and 200, and generally averages between 10 and 40.

Taking actual manometer readings on hydraulic pressures and using the extrusion formula, the values of resistance to deformation of the metal as a function of temperature is found to vary between 10 and 30 kg/mm² (15,000 and 50,000 lb. per sq. in.).

Curves which show resistance to deformation as a function of temperature in fact approach straight lines.

Whenever metal of a new analysis is treated, two extrusion tests are run at different temperatures, and the characteristic straight line curve is plotted from these points. After this, all the factors relating to the extrusion of this analysis for a given press are available.

Furthermore, it seems possible to determine resistance to deformation by pilot tests, which obviously would be a more economical method. This study as well as many others is part of the current research program.

After these explanations, the great importance of lubrication in extrusion technology will be appreciated.

(4) Lubrication. When the billet is placed into the container and then pushed through the die, there are a number of areas where lubrication can either render possible extrusion of longer billets or reduce the wear of the tools by reducing friction.

There are actually three such areas: (1) the face of the billet, where it comes up against the die; (2) in the extrusion of tubes, the area at which the interior of the billet encounters the mandrel as the bore of the extruded product is formed; and (3) the exterior of the billet, where it is pressed against the container. These different areas of friction will be discussed in some detail below.

Forward Face. A certain amount of solid glass is placed in contact with the die, and a hot steel billet then touches the free face of the glass. The problem is that of the behavior of the glass placed as it is between billet and die.

In Fig. 6 the thickness of the glass is shown as abscissa and the temperature as ordinate. The glass placed against the die is at a temperature somewhat below that of the tool, which latter is about 200 C. (390 F.). The face of the glass in contact with the billet is brought very rapidly to its temperature, i.e., about 1200 C. (2190 F.).

At the beginning of extrusion, i.e. when $t = 0$, no heat has as yet passed into the glass. The curve representing temperature of the glass shows only a slight gradient and is therefore nearly parallel to the axis of the abscissa. In actual practice there is a very rapid heat transfer so that at the end of one second, when $t = 1$, the temperature curve (which can be calculated) assumes the form shown by the second curve above the axis of abscissa in Fig. 6.

However, it must not be forgotten that the

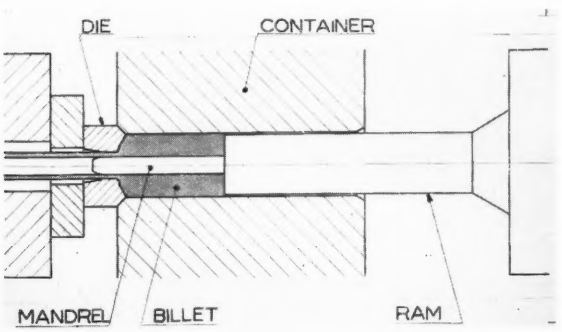


Fig. 4. Extrusion of a tube.

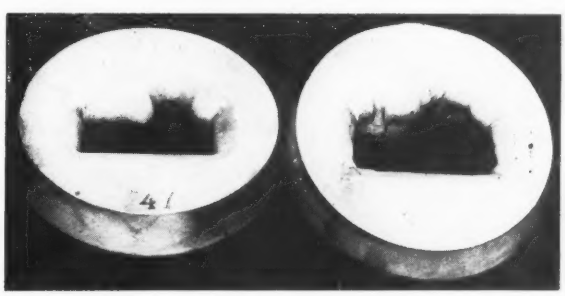


Fig. 5. Extrusion of steel without lubrication; (left) new die; (right) die after partial extrusion of a steel billet.

billet is pressed against the glass under a load of between 50 and 100 kg/mm². Hence, an entire glass layer brought to a temperature above its fusion point then flows with the metal out through the die. As the first layer of glass escapes under pressure, a new layer of glass comes in contact with the hot billet and also flows with the metal. Finally, the entire extruded bar is covered by a layer of glass, the thickness of which is in the order of magnitude of 2/100ths of a millimeter.

The essential principle of glass lubrication should be noted here: The glass fuses at the interface in touch with the metal to which it adheres; thus, the lubricant used is in a state of incipient fusion and not free-flowing. If this were not so, i.e., if a lubricant were used which flows freely, it would be ejected in a disorderly manner and the continuous flow that is a feature of glass would not come into play. To confirm these considerations, experiments were made with copper as a lubricant. Here the entire amount of copper placed in the container covered the first foot or two of the extruded bar in the shape of discontinuous spots. On the rest of the bar there was no trace of copper. Since there was direct contact between the hot metal and the die, the latter was badly worn and out of service before a single bar had been extruded.

An attempt was also made to modify the thickness of the glass film by varying: (1) the orifice of the die, (2) the extrusion rate, and (3) the type of glass. In this connection it is desired to acknowledge the important assistance which was received from the glass research laboratory of the Saint-Gobain Company, especially as it related to the study and production of different analyses and types of glasses which were required to solve extrusion problems. At their suggestion, the thickness of the glass film on the extruded bar was determined with considerable accuracy by using radioactive tracers.

In another test a layer of radioactive glass placed against the die was found as a minute trace upon the extruded bar, showing that under certain conditions the glass layer which is in contact with the die can be mechanically entrained. Thus some of the glass takes part in the lubrication process although it has not had time to melt. This effect is, incidentally, not advantageous for the life of the tool as the cold glass is highly abrasive.

It will be readily understood that the extrusion rate has a great bearing on the thickness of the glass film. The layer formed follows a law which establishes thickness as a function of time. The surface to be lubricated depends both on the shape of the profile and the extrusion rate. In practice, extrusion should be conducted as rapidly as possible, the rate of issue of the bar from the die being in the order of 6 meters per sec. The extrusion operation thus does not take longer than 2, 3, or 4 seconds, depending upon the length of the product. This special feature demands a complete modification of the concept of extrusion presses for steel.

Two properties are of principal importance in glass lubrication: the heat diffusivity and the viscosity of the glass used.

The heat diffusivity is represented by the formula $\lambda/8C$, i.e. the ratio of the heat conductivity to the product of specific heat and specific weight. It is the ability of the glass to diffuse the heat transmitted by the hot metal. Unfortunately the values of this property lie very close together in all glasses, and it was not possible to make practical use of this factor to any extent. However, diffusivity does not coincide with viscosity, and the control of viscosity plays an important part in extrusion where products are worked at different temperatures. This is particularly critical as temperatures increase from that required for the extrusion of titanium to that of high-speed steels, cast iron, mild steel, stainless steel, and high-temperature steels, to the very high temperature demanded by molybdenum and its alloys.

A whole range of vitreous products of widely varying viscosities is available so that lubricant and material may be properly matched. But the results can still differ according to the physical character of the glass employed. In the beginning, simple glass plates were used to lubricate the die. This form of glass had two shortcomings: there was first of all the difficulty of obtaining plate glass at low cost. It was necessary to use a product having other applications which determined the production rate. Glass-making furnaces are actually slow operating devices and they are not put into operation except for lengthy campaigns. In practice, window glass had to be used which is manufactured in only a narrow range of qualities. Secondly, under the pressure of the billet the glass plate broke at the start of the extrusion cycle. Cer-

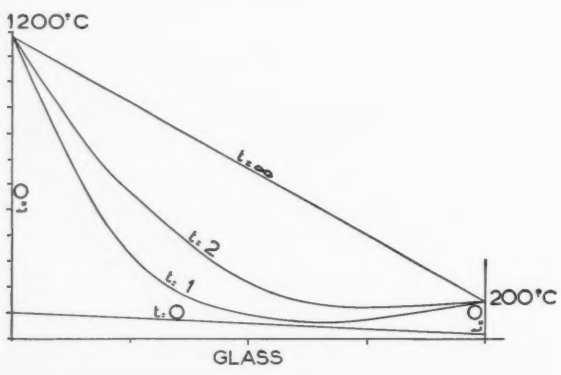


Fig. 6. Glass temperature as a function of its distance from hot metal and container wall at different times.

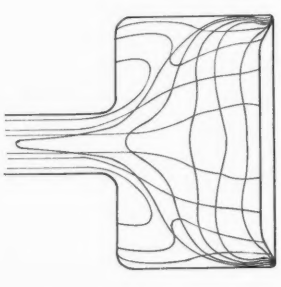


Fig. 7. Diagrammatic representation of flow during extrusion without glass lubrication.

tain parts of the die might be exposed to direct contact with the billet, at least during the first moments of the extrusion before the continuous lubrication had become fully effective.

It was therefore attempted to perfect lubrication by using a type of glass known as multicellular glass which was available as a kind of glass sponge. It is produced by heating glass powder mixed with an effervescing agent to a suitable temperature. However, this material did not give satisfactory results either, owing to excessive wear of the die by erosion. Finally glass wool was tried and found suitable for this new method of lubrication. Heat insulation type wool was used, but it had to be free from any fat. As it is generally marketed, glass wool contains some fat to facilitate its handling. The disadvantages of glass wool, to an even greater extent than that of plate glass, is the fact that it is produced in only a very limited range of qualities. Currently it is being attempted to develop the use of types of glass which will be less expensive and more easily available in a wide range of compositions.

It might be of interest in this connection to outline the manner in which die wear was studied with the help of radioactive materials: It was possible to develop superficial radioactivation of the die by dipping it into a radioactive solution of phosphoric acid. Thus, a radioactive layer was produced about a hundredth of a millimeter thick, the intensity of which was measured before the extrusion run by means of photographic paper. Then a bar was extruded. Wear corresponds to the removal of a particle of the die by the extruded bar. By moving a Geiger counter along the bar it was possible to determine the places where radioactive particles had been deposited on it, and thus where erosion had occurred and the degree to which such erosion had taken place on the die. By placing a new piece of photographic paper upon the die, it was possible to see which areas of the die had worn. This method has produced some very interesting results.

Interior Surface. Internal friction between billet and mandrel must be lubricated. Here the principles are the same as in die lubrication. Nevertheless, there is a larger operating surface at least in the classical case where the mandrel advances with the ram. The problem therefore is somewhat less complicated, and it should be noted that sound tubes have been made by lubricating the mandrel with graphite or even without any lubrication. However, without lubricating the mandrel it is impossible to extrude tubes of 1 to 3 mm. wall thickness, or of 20 millimeters I.D., such as are being produced using glass lubrication.

In the beginning, the mandrel was lubricated with glass tubes; even glass cylinders from oil lamps were used which were readily available during the war. Breakage of these tubes caused numerous defects which were all the more annoying, since they were located inside the tube and therefore difficult to discover. Sleeves of glass sheet were subsequently used, followed then by glass cloth. Now a special product is in use called socks; these are fibres braided to form a kind of hose which has the advantage that no preparation of any sort is required before the extrusion cycle. It is, however, still necessary to use commercially available glass types for these fibres. Efforts are being made in the direction of using other physical forms of glass providing lower cost and more convenient handling.

Exterior Surface. Finally, the friction of the surface of the billet against the container must be minimized by lubrication. This problem was found to be the least difficult to solve, and it did not require any special attention except where steels such as stainless are processed. For this application, sheets of glass were employed to envelop the billet just before it was introduced into the container. Currently, low-fusing glass powder is used. It is rather strange, incidentally, that the glasses employed for surface lubrication do not assist in the formation of the film produced on the bar. It seems that the surface glass is lodged in the residue of glass facing the die which has not been consumed.

This practice has been successful in practically eliminating friction, as can be observed by the pressure curve drawn up during the travel of the ram in the extrusion cycle. Under operation without lubricating the surface of the billet, these curves show a point at the start which represents the effort required in dislodging the billet from the container walls. They decrease proportionately as the length of the billet decreases in the container. On the other hand, when the surface of the billet is lubricated horizontal curves are developed, sometimes even slightly rising curves owing to the cooling of the billet during extrusion. Here, the great

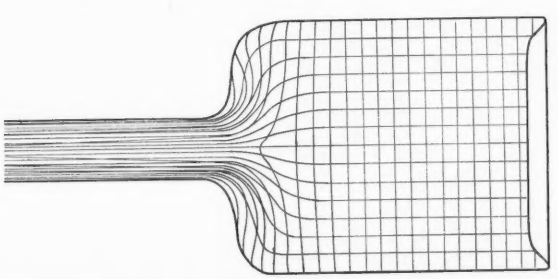


Fig. 8. Diagrammatic representation of flow during extrusion under glass lubrication.

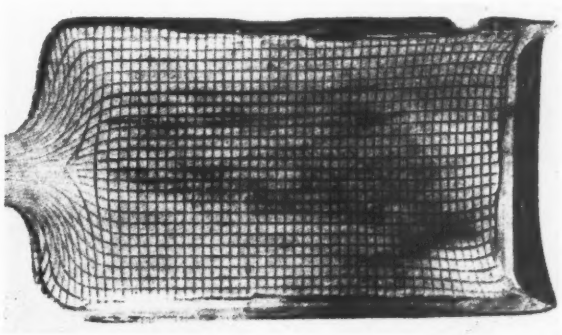


Fig. 9. Actual cross-section of test-run of stainless steel billet under glass lubricated extrusion.

advantage is that much longer billets can be extruded and substantially greater quantity of products can be obtained, thereby reducing conversion costs.

(5) Flow of Metal. By using glass wherever friction should be reduced, a parallel flow in the extruded metal has been developed, i.e. the old theories which describe flow during extrusion as a succession of giant fingers which nest one in the other no longer apply. Two methods have been used to study the flow of metal during extrusion:

1. In studying the flow of metal as a mass, the billet was cut in two through the center, then a coordinate system of lines was scribed about 5 millimeters apart upon the plane of the joint. Finally, the billet was welded together again and extruded. Generally the extrusion operation was stopped about half way through. The extruded portion and the billet still in the container were then removed from the press and separated along the earlier plane of cleavage. The tracings were still very clear along the plane of the joint, and it was possible to study their course after deformation. This method permitted an experimental evaluation of the mathematics developed by those who have studied the deformation of metals.

Fig. 7 shows a diagrammatic picture of the lines obtained after extrusion of a billet which had been marked as indicated above. This billet was extruded without glass lubrication; the lines were badly twisted and the skin of the billet penetrated into the mass of the metal. Without lubrication, friction upon the tool was such that the metal making up the skin of the billet found it easier to penetrate into the mass, upsetting its flow, than to continue to flow upon the unlubricated surface.

Fig. 8 shows the design developed after partial extrusion of a billet which was subjected to the same preparation but had its flow lubricated by glass. Here the flow took place "as a block." The metal glided in the container, pushed by the ram, and was deformed in an orderly and regular manner upon approaching the tool, the skin of the billet becoming the skin of the extruded bar.

To amplify the story told by the diagrammatic drawings of Figs. 7 & 8, a photograph of a half billet treated in accordance with the method set forth above is presented in Fig. 9.

2. The other method used to study the flow of metal employed the property of lubricated flow to retain the skin of the billet in the skin of the extruded bar. This method consisted in simply threading the billets to be extruded. A thread with a pitch of a few millimeters and with a depth of about a millimeter was machined upon the cylindrical surface of the billet. These tracings were found again upon the extruded bar and it was possible to measure differences as a function of the length of the bar, of the distance of any given point to the part of the bar which was extruded first, and of the form of the tools. This method permitted also determinations of variations in the operation on the basis of different planes laid through the axis of the billet, as distinct from the first method which cannot develop this information. Generally stainless steel billets were used in these experiments as they retain the thread better.

Both methods verified that the metal flows steadily and constantly under glass lubrication. These flow studies have had a profound and beneficial effect upon the design of the container base, more generally known as the die holder, and certain surface defects on the extruded bars have thus been eliminated.

After the bar has been extruded with glass lubrication, the glass must be removed. In fact, while glass is a particularly good lubricant at high temperatures, it is a rather strong abrasive at low temperature. Press designers have learned this at heavy cost. In practice, the operation of removal of the glass is accomplished by adding hydrofluoric acid to the usual sulphuric acid pickling liquor. It is also possible to use molten soda in the same manner. An improved method is to subject the extruded piece to the action of a stretcher-straightener which removes most of the glass, thus greatly shortening the subsequent pickling time and presenting the further advantage of yielding a straightened product. These are the main aspects of the technique of glass lubrication.

(6) Current Research. Although glass has greatly contributed to the development of steel ex-

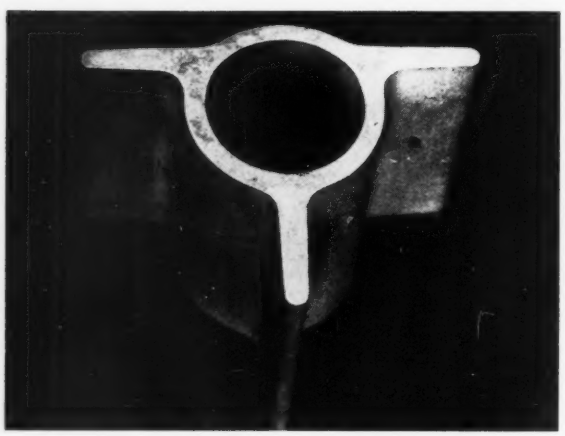


Fig. 10. Ribbed tube extruded under glass-lubrication.

Fig. 11. Stainless steel with case extruded under glass-lubrication.

trusion, not all the difficulties have been overcome. Among the problems that are left, and on which research is being currently conducted, are the following:

At present, preheating of billets is performed in a molten bath of barium chloride to avoid scale-formation. This method is found to be relatively expensive and, therefore, tests are being pushed forward to develop alternative heating methods. Standard heating in a gas or oil-fired furnace, followed by a descaling in water under pressure or by deformation, is being considered as well as electric induction heating using frequencies in the order of 400 cycles suited to the dimensions of the billets to be extruded. Both methods are promising and in the near future salt bath heating may be abandoned.

Cross-sectional tolerances are another problem on which much work is being done. Although tolerances in glass-lubricated extrusion are closer than those obtained in rolled products of the same shape, efforts are being directed to further improve them; so that in this hot working, tolerances will be achieved which approach those of cold drawn products. Obviously this is very difficult, but substantial progress is expected in this field.

(7) Properties of the Extruded Steel Products. Extrusion imparts certain properties which clearly distinguish it from other processes.

1. It assures deformation under pressure from three directions. If certain precautions are taken, it permits a deformation which avoids areas under tension. Thus, metals which are particularly difficult to form can be extruded, such as high-speed steel with 18% tungsten, or the S 816 alloy with 40% cobalt, or nodular cast iron.

2. By extrusion, the metallurgical quality of the formed metals can be adjusted. Extrusion, per se, taking only a few seconds in certain cases, e.g. in the extrusion of stainless steels, the extrusion temperature can be controlled with considerable accuracy. The shaping takes place isothermally and heterogeneities in the structure of the extruded bar are avoided.

3. Surface quality of the extruded product is particularly sound, and in some cases hot-finished products can be delivered direct to the customer, while in others the product delivered to the drawing and finishing plant is of outstanding quality.

4. The extrusion process requires relatively low-cost tools which permits conducting small campaigns; while the competing process, rolling, requires the provision of costly rolls which can only be amortized by extended production runs.

5. There is no disengagement of the channels of the rolls and thus it is possible to extrude profiles, to produce complex sections of finned tubing or other shapes that cannot be rolled. Fig. 10 offers an example of this type of product.

Fig. 11 shows a wrist watch case extruded as a shaped tube. The raw extruded product and the finished part produced after cold drawing are shown.

It is also possible to make tubes with tapered sections by means of different measures taken on positioning the mandrel or the die. Thus it has been possible to produce tubes with a constant internal outline but with a variable thickness.

Finally, in Fig. 12, an example is shown of a cross-sectional profile of a turbine blade which is obtained directly by extrusion.

It is also possible to produce clad metals, for instance jail bars, which are made with ordinary steel on the outside but have a highly tensile insert of Hadfield manganese steel. The prisoner who wants to make a break starts on the ordinary steel with a file, but cannot do anything against the manganese steel. However, he leaves a visible cut for the warden who only has to change the cell.

Clad tubing is another interesting product; for example, one with stainless steel on the inside to carry corrosive media, and low alloy nickel chrome steel on the outside for mechanical strength.

In the commercial exploitation of a new process, new outlets sometimes appear in an unexpected manner. For instance, a boiler tube with two longitudinal ribs was made as it was thought that this tube had a moment of inertia greater in one plane than in another, and that without a substantial increase in weight this tube would better resist deflection under its own weight. However, boiler manufacturers evinced no interest. This matter was forgotten until one day important orders were received for ribbed tubes which came from a customer who was not at all interested in resistance to deflection, but who was much more interested in the fact that it was possible to channel gases along the tubes by means of these ribs.

These examples, chosen at random from among a great many others, give the impression that the surface has only been scratched in this field. Recently, in collaboration with engineers of L'Air Liquide, rounds were extruded that are suitable for the production of special welding electrodes, carrying axially a special flux located in a channel or a number of channels which run parallel along some 50 meters of extruded bar and have a diameter of some tens of millimeters. Along the bar the quality of the flux or its quantity can also be varied. Glass lubrication applies equally to the hot-piercing of steel, and tests are being run both in France and in other countries to study application of this method to other forms of hot metal-working particularly to hot upsetting.

Special glasses render possible a modification

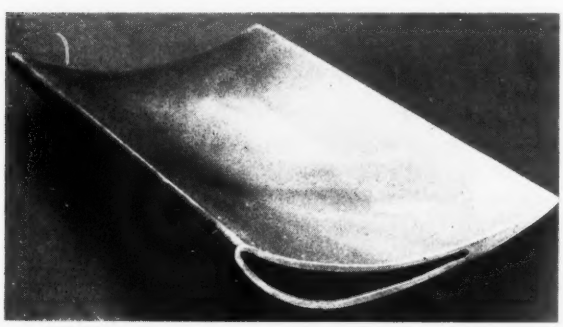


Fig. 12. Turbine blade extruded under glass-lubrication.

in the range of applications by using different glasses for different temperatures. The advantages of glass lubrication which were apparent at 1200 C. (2190 F.) are thus available at higher and lower temperatures. At present in England and in the United States tests are being run on the glass lubrication of the extrusion of special bronzes and light alloys.

Section News

BALTIMORE, September meeting. J. F. McGrogan, Grease Research Supervisor, The Atlantic Refining Co., presented a paper entitled "Driver's Reaction to Chassis Lubricant Performance."

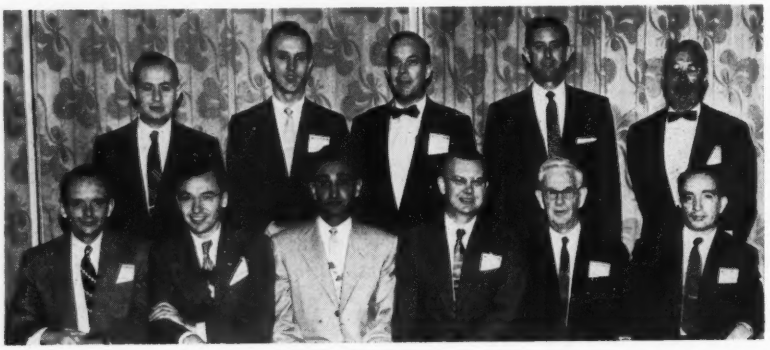
October, "Lubricating Oil Additives," by Dr. M. I. Smith, Lubrication Engineer, Socony Mobil Oil Co.

November, "Oil Seals & Packing Cups," by H. Landis, Johns-Manville Corp. (Submitted by R. L. Humphreys, Sec'y.)

CHICAGO, October. Dr. R. H. Leet, Standard Oil Co. (Ind.), presented a paper entitled "Tools for Grease Research." (Abstract: Because of the complex nature of grease, many tools from the arsenal of physical chemistry are used to investigate its properties. Crystalline changes of soaps used as thickeners are determined by the calorimeter, dilatometer, polarizing microscope, and X-ray spectrometer. Flow properties are studied by the capillary and rotational viscometer and the polarizing microscope. Structure is interpreted by the darkfield and electron microscopes, X-ray spectrometer, and light-scattering photometer. These tools help solve widely different problems related to the nature and behavior of grease.)

November, "Lube Oil Additives," by J. R. Griffin, E. I. duPont deNemours & Co.

1956 Program Schedule: **January 19,** Dr. M. E. Merchant, Cincinnati Milling Machine Co., "Cutting Oils;" **February 16,** Ladies' Night; **March 15,** I. J. Regula, Inland Steel Co., "Steel Mill Lubrication;" **April 19,** G. K. Malone, General Motors Research, "Passenger Car Lubrication;" **May 17,** Dr. W. H. Millett, Carbide & Carbon Chemicals Co., "Fire-Resistant Hydraulic Fluids;" **June 21,** Golf Party. (Submitted by J. N. Waddell, Sec'y-Treas.)



INDIANAPOLIS, ASLE-ASME Lubrication Conference. The Indianapolis Section of ASLE and the central-Indiana Section of ASME were joint hosts at the 2nd Annual ASLE-ASME Lubrication Conference held in Indianapolis, Ind., on Oct. 10-11-12, at which 262 lubrication engineers and research scientists attended. Pictured above are the members of the ASLE-ASME Lubrication Conference Committee as follows: (1st row, l. to r.) Dr. E. R. Booser (ASLE Secretary), General Electric Co.; E. E. Bisson, NACA Lewis Flight Propulsion Lab.; S. Abramovitz (Conference Vice-Chrmn.), Franklin Institute of Pennsylvania; Dr. D. F. Wilcock (Conference Chrmn. & ASME Lubrication Activity Div. Chrmn.), General Electric Co.; Dr. B. L. Newkirk; and A. E. Cichelli (ASLE Director), Bethlehem Steel Co. (2nd row, l. to r.) Dr. E. Rabinowicz, Massachusetts Institute of Technology; D. B. MacDougal, ASME Headquarters; W. P. Youngclaus, Jr. (ASLE Administrative-Secretary), ASLE Headquarters; S. R. Calish, Jr. (Chrmn. of ASLE Technical Committee on Gears & Gear Lubrication), California Research Corp.; and E. D. Harkins, Sr. (ASLE Midwestern Regional Vice-Pres.), The Farval Corp.

FORT WAYNE, October. R. McMahan, Socony Mobil Oil Co., an authority on developing fuels and motor oils and a technical consultant for the Indianapolis 500-mile Speedway Races, previewed a color film of the 1955 500-mile race, followed by a discussion of "behind-the-scenes" happenings which do not get into print. (Submitted by J. W. Buckner, Chrmn.)

NEW YORK, September. G. Gleim, Technical Engineer, Esso Standard Oil Co., previewed an Esso film entitled "Smoothing the Way" (dealing with the subject: "The Vital Story of Industrial Lubricants"), followed by a Question & Answer period.

October, "The Present and the Future in the Automotive Field," by J. Campbell, Technical Director, General Motors Corp.

November, "Gear Failures," by C. R. Purdy, Socony Mobil Oil Co.

December, "Carelessness Costs You Money" (Panel).

1956 Program Schedule: **January 17,** "How to Sell a Lubrication Program to Management" (Panel), L. T. White, Cities Service Petroleum Corp., & W. McKaig, IBM Corp. (Panelists); **February 14,** Ladies' Night; **March 20,** "Special Purpose Greases," by a technical representative from Baroid Div., National Lead Co.; **May 2,** "Industrial Automotive Equipment" (Panel). (Submitted by E. Landau, Publicity Chrmn.)

PITTSBURGH, September. C. DeLancellotti, Ethyl Corp., presented "Fire Power Show," a demonstration of the new and approved methods for the safe handling of gasolines and other flammable liquids. (Submitted by S. W. Settle.)

(Continued on p. 431)

Fluids For The Grinding Of Titanium

by E. J. Krabacher*

The machining of titanium has presented many difficulties, particularly in regard to grinding where wheel loading and wheel wear have been critically high. The present paper describes the development of a grinding fluid based on sound metal-cutting principles. A glass-streak test was used for screening, since potentially useful grinding fluids prevent wetting of glass by titanium.

The application of titanium as a structural material has been beset with difficulties. Many problems have been encountered both in the manufacture and fabrication of titanium and its alloys; the machining of this material alone having raised many involved and intriguing problems. Of the many difficulties encountered in machining, perhaps the greatest has been in precision grinding. The extremely rapid wheel loading together with the resultant high rate of wheel wear have, until recently, made the production grinding of titanium impractical. Attempts to grind titanium with conventional grinding fluids, wheels, and practices have resulted in exceptionally low grinding ratios (volume of metal removed to volume of wheel worn away), poor finish, and often troublesome chatter.

At first glance titanium and its alloys would seem to present no serious difficulties in grinding. Its physical properties are no more severe than those of numerous stainless and alloy steels which are readily ground; yet extreme difficulty in grinding this material exists. If these problems cannot be resolved by conventional methods — juggling grinding fluids, wheels, and conditions, one against the other — a more fundamental approach is needed. Such an approach requires an understanding of the basic factors which produce this very rapid wheel loading and wheel wear.

The Problem. The grinding process is a true metal cutting operation; one in which each individual active grit acts as a cutting tool to remove a minute chip upon each contact with the work. Therefore, those basic factors which play so important a part in the machining of titanium, properly interpreted, may be considered a sound guide in considering the grinding process.

Research into the fundamental factors affecting the machining of titanium, as distinguished from grinding only by definition, indicates three intrinsic properties of titanium which may be considered as the primary factors contributing to the extreme difficulties encountered in the precision grinding of this metal. These factors are: (1) high mutual solubility of titanium in most other metals and refractories at elevated temperatures; (2) poor thermal conductivity and volume specific heat characteristics; and (3) a very high chip-flow velocity due to the inherently high shear angle in the chip forming process. The two latter properties above result in grinding temperatures for titanium much higher than those obtained when grinding steels of equivalent physical properties. These high temperatures, together with the high mutual solubility of titanium at these temperatures, subject the individual grinding grits to a combination of two processes of wear. These are: direct attrition and dulling of the grits by solution, and "solution bonding" of titanium to the grits causing "capping" and resultant fracture or dislodgement of the grits. The relative amount of attrition and fracture-wear will depend on the severity of the grinding action, grinding fluid used, and on such wheel-structure factors as the type of grain and strength of bond.

Approach to the Problem. The above evaluation of the problem would indicate three likely possibilities for improving the grinding of titanium. The first is to impose, by action of a cutting fluid, a low-shear-strength solid film between the surface of the grit and the titanium chip, to reduce or prevent solution by reducing or preventing direct contact between metal and grit at the high temperatures involved in grinding. The second possibility is to manufacture a grinding wheel from a refractory which is not mutually soluble with titanium (if such exists), or to develop a wheel of conventional refractories which will, by the nature of its structure, reduce to a minimum the wear by attrition and fracture. The third possibility is to reduce the grinding temperature (temperature at the chip-grit interface). This reduction in temperature reduces the tendency for solution between the grinding grit and the titanium metal, thus reducing the attrition or capping of the grits.

From previous research in chip formation, it appears that there are three primary means of lowering the grinding temperature: (1) reduction of the amount of heat generated in the grinding proc-

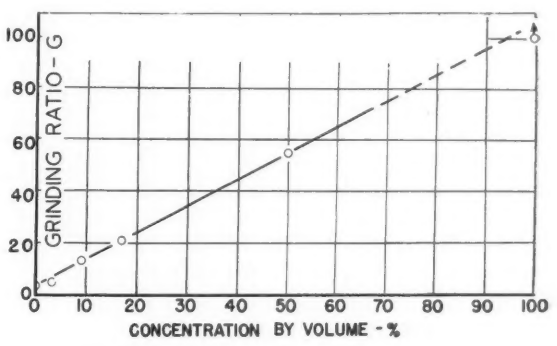


Fig. 1. Grinding ratio vs percent concentration of experimental fluid 95-70 in kerosene; surface grinding titanium—Ti 150A.

*The Cincinnati Milling Machine Co., 4701 Marburg Ave., Cincinnati 9, Ohio.

ess by the use of a more effective grinding fluid (i.e., one capable of the interposition of a low-shear-strength solid film between the contacting surfaces of grinding grit and chip); (2) more rapid dissipation of the heat which is generated, by applying an effective coolant; and (3) the reduction of the rate of heat generation by reducing grinding wheel speed.

It is evident from an evaluation of these three means of lowering grinding temperature that the first is by far the most desirable. If we can eliminate most of the heat generation at its source, our problem is most directly and satisfactorily solved. It is evident also that the third means of lowering grinding temperature is the least desirable. Reducing the grinding-wheel speed undoubtedly reduces the rate of heat generation, consequently lowering the grinding temperature under similar conditions of cutting-fluid application. It must be borne in mind, however, that reduction of grinding-wheel speed requires a corresponding reduction in rate of metal removal to maintain a given chip per grit. We should not therefore look to reduced grinding-wheel speeds as the ultimate solution to our problems, but rather to a combination of grinding fluid and grinding wheel which will give results in line with good grinding practice.

From the foregoing examination of the problems involved, and the possibilities for solving them, the most direct approach appeared to be through the development of an effective grinding fluid. This fluid, in order to be effective, must be capable of preventing or greatly retarding the solution action of the titanium metal with the grinding wheel grits at the high temperatures involved in grinding.

Screening Tests. With the background and needs advanced, the necessity arose for a rapid method of screening numerous materials likely to possess the required properties. It was known that titanium metal would wet glass when brought into contact under relatively high contact pressure and rubbing speed; that is, the mutual solubility of glass and titanium caused the titanium to "weld" to the glass much the same as the grinding wheel grits are capped when grinding titanium with conventional fluids and wheels. It seemed reasonable that fluids which would prevent the wetting of glass

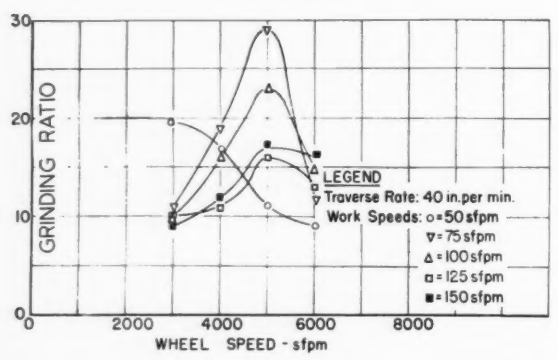


Fig. 2. Effect of wheel speed and work speed on grinding ratio.

Table I. Screening of fluids with simple surface grinding set-up.

Grinding Fluids	Grinding Ratios		
	1000 sfpm	3000 sfpm	6000 sfpm
Dry	0.67	4.43	0.66
Oleic acid	26.2	16.1	---
Sorbitan monooleate	22.0	16.1	---
Wetting agent (25% aq.)	18.8	---	---
Carbon tetrachloride	22.2	---	---
1 part carbon tetrachloride & 1 part lard oil	---	55.	---
Lard oil	---	17.5	1.44
P-47 way lubricant	---	5.7	---
Experimental fluid 95-70 (high additive, E.P.)	---	>100.	8.0
1 part experimental fluid 95-70 & 1 part kerosene	---	55.6	2.65
Kerosene	---	3.0	---
Commercial grinding oil (250 vis.)	---	9.2	0.47
Saturated borax solution	---	4.3	---
Commercial soluble oil concentrate (high soap)	---	4.0	---
Commercial soluble oil (20% concentration in water)	---	2.95	---
Commercial chemical emulsion type grinding fluid (concentrate)	---	4.4	---
Commercial chemical emulsion type grinding fluid (10% concentration in water)	---	4.4	---

in this manner would be worthy of further consideration; conversely those which would not, might be eliminated. While it is not certain that this test is directly analogous to grinding fluid performance under grinding conditions, it did make possible the rapid screening of many commercial, special, and experimental fluids. Those fluids which passed this test were subjected to further screening tests along with additional fluids found to be of interest. The next screening phase was in the form of a simple surface grinding operation in order to evaluate them for grinding performance with respect to grinding ratio. Some thirty fluids were evaluated under these test conditions. Early investigations indicated that most of the above screened fluids gave reasonable values of grinding ratio at the very impractical grinding wheel surface speed of 1000 fpm. Grinding ratios obtained for several typical fluids under the above conditions are listed in the first column of Table I. Tests were therefore discontinued at this very low grinding speed in preference to more severe conditions of 3000 fpm grinding wheel speed. From the second column of Table I, it may be seen that only a few of the fluids yielded reasonable grinding ratios in the presence of these higher grinding temperatures.

At this point it became evident that the ex-

Table II. Internal grinding. Work material: Ti 150A (Rc 37-38); grinding fluid: experimental 95-70; grinding wheel: experimental No. 1140, 11¼ x 1¼ x ⅜; grinding wheel surface speed: 400 fpm; work speed: 75 fpm; internal diameter of work: 3¾".

Metal Removal (in. on dia.)	Wheel Wear (in. on dia.)	Grinding Ratio = Volume of titanium / Volume of wheel
0.144	0.0045	72
0.148	0.0030	111
0.060	0.0017	114
0.056	0.0018	98
0.088	0.0020	97

treme pressure (E.P.) type fluids performed in a manner far superior to any other type of fluid. Here we see that the experimental fluid 95-70 (now called Cimcool "Titan") gave grinding ratios in excess of 100, while the grinding ratios obtained with carbon tetrachloride and the 95-70 diluted 50% by volume with kerosene were about 55. This experimental fluid was next evaluated for performance at a conventional grinding wheel speed of 6,000 fpm, along with a few other fluids. Carbon tetrachloride was not run at this high speed due to its extreme volatility. From column three of Table I it may be seen that only the experimental, high E.P. type, fluid yielded a reasonable grinding ratio. While this fluid would not necessarily be the final answer, it did indicate the type of fluid required to grind titanium successfully at reasonable grinding wheel speeds. Further tests with this fluid at 3000 fpm grinding wheel speed, Fig. 1, indicated that the dilution of this fluid with kerosene decreased the resulting grinding ratio in direct proportion to the amount of kerosene present. Thus it became apparent that in order to be effective at even higher grinding speeds this type of fluid would have to be used at full concentration.

The type of fluid which would successfully grind titanium was now apparent. This was the time to discontinue screening tests and to evaluate performance under typical production grinding conditions. For these tests a 10" Universal grinding machine was chosen with a typical setup for cylindrical (external) traverse grinding. Under these conditions several additional experimental fluids of

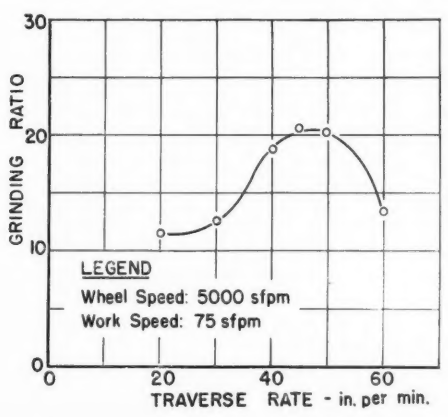


Fig. 3. Effect of traverse rate on grinding ratio.

Table III. Cylindrical grinding. Work material: Ti 150A; grinding fluid: experimental 95-70; grinding wheel: experimental No. 1182, 14 x 1 x 5; grinding wheel surface speed: 3850 fpm; work speed: 75 fpm; outside diameter of work: 2⅛" (nominal).

Work Dia. (at end of run) (in.)	Metal Removal (in. on dia.)	Wheel Wear (in. on dia.)	Grinding Ratio = Volume of titanium / Volume of wheel
2.252	0.089	0.001	64
2.164	0.089	0.001	61
2.073	0.089	0.001	59
1.981	0.089	0.001	56

the same type were evaluated along with the 95-70 fluid, in combination with numerous grades and types of grinding wheels. At this point concurrent studies of the internal grinding operation led to the discovery that a particular combination of grinding wheel and an experimental grinding fluid gave excellent results as presented in Table II. This same fluid in combination with a similar wheel also yielded excellent results in the case of the cylindrical grinding operations as given in Table III.

Here it may be seen that grinding ratios of the order of 55 to 65 were obtained at 3850 fpm with excellent finish and no chatter. Further studies, Figs. 2 and 3, indicate that optimum grinding conditions, for this particular combination of grinding wheel and grinding fluid, would appear to be 5000 fpm grinding wheel speed, 75 fpm work speed and 40 to 50 inches per minute table traverse rate. The values of grinding ratio indicated in Figs. 2 and 3 are useful as relative values only. These values are considerably lower than would normally be obtained due to the relatively small volume of metal removed after truing of the wheel. This is associated with the usual high rate of wheel wear which normally occurs with a freshly dressed wheel.

Fig. 4 indicates the values of grinding ratio obtained when grinding titanium (Ti 150A) under the optimum conditions given above. Here it can be seen that the hardness of the material has a very significant effect on grinding ratio. Values of grinding ratio vary from an average of 68 for a Rockwell "C" hardness of 35 to an average value

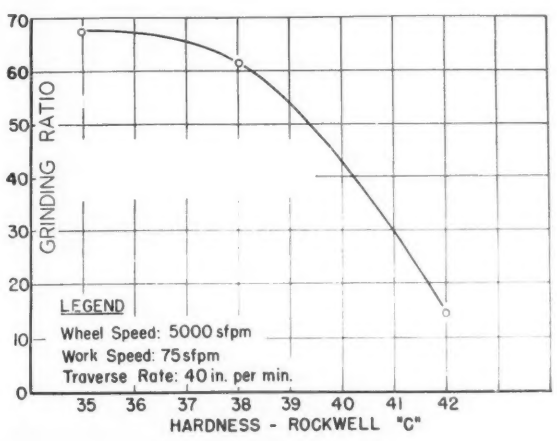


Fig. 4. Effect of hardness on grinding ratio.

of 15 at a Rockwell "C" hardness of 42. These high grinding ratios together with the large volume of metal removal possible before the wheel requires redressing indicate that production grinding of titanium and its alloys is possible with the proper combination of grinding wheel and grinding fluid.

It is adequate to say here that under surface grinding conditions the results obtained with the above-mentioned experimental grinding fluid are actually slightly superior to those obtained under cylindrical grinding conditions.

The photomacrographs of Figs. 5, 6 and 7 serve to illustrate the effectiveness of the proper combination of grinding wheel and grinding fluid when grinding titanium; in this case Ti 150A. Fig. 5 illustrates the work surface of a conventional aluminum oxide grinding wheel used in combination with a conventional water-base grinding fluid under surface grinding conditions. It may be seen that in this case the removal of 0.02 in.^{3} of titanium has resulted in considerable loading and extensive dulling of the grits. Fig. 6 presents a more detailed look at several of these "capped" or loaded grits. Fig. 7, on the other hand, illustrates the grinding wheel work surface after having removed 0.60 in.^{3} of titanium with the special combination of grinding wheel and grinding fluid under the same grinding conditions. Here it may be seen that while 30 times the amount of metal was removed, there is no sign of loading or dulling of the grits, thus demonstrating the effectiveness of the proper combination of grinding wheel and grinding fluid. An understanding of the vast improvement in performance obtained with the proper combination of grinding wheel and grinding fluid may be obtained from a comparison of the resulting chips as shown in Figs. 8 and 9. Fig. 8 is a photomicrograph showing typical chips obtained with the conventional wheel-fluid combination. Here it may be seen that the chip formation was very poor, giving evidence of grinding temperatures which very nearly approached the melting temperature of the titanium. On the other hand, the chips obtained with the effective wheel-fluid combination, Fig. 9, show evidence of much better chip formation and much lower grinding temperatures.

The Solution of the Problem. A satisfactory solution to any problem depends upon the usefulness of the answer. Here the problem was that of developing a fluid which would substantially contribute to the satisfactory grinding of titanium on a production basis. An evaluation of this answer may be obtained from the typical example set forth below.

Here are the results obtained from a short production run on 64 titanium bearing housings, RC-130B, for a jet engine. The first operation called for simultaneously plunge grinding the outside diameter and facing the flange square within close tolerances, Fig. 10. The housings were held in a six-jaw universal chuck. The wheel head was swivelled 45° to facilitate plunge grinding. The width of the OD cut was $\frac{5}{8}$", and the flange width was $\frac{1}{4}$" with three $\frac{5}{8}$" ears spaced 120° apart.

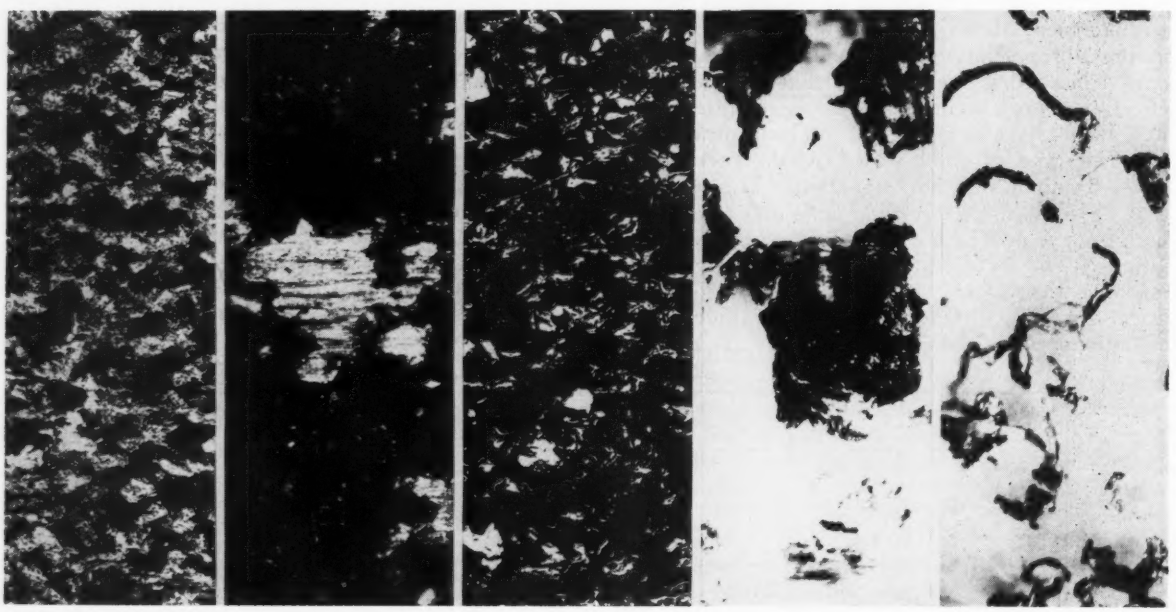


Fig. 5 (left). Photomacrograph showing dulled and loaded grits after removing 0.02 cubic inch of titanium with conventional wheel and fluid.

Fig. 6 (second from left). Photomacrogrph showing detail of "capped" grinding wheel grit from Fig. 5.

Fig. 7 (center). Photomacrograph illustrating grinding wheel grits after removing 0.60 cubic inch of titanium with effective combination of grinding wheel and grinding fluid.

Fig. 8 (second from right). Photomicrograph illustrating poor chip formation with a conventional combination of grinding wheel and grinding fluid.

Fig. 9 (right). Photomicrograph illustrating good chip formation with an effective combination of grinding wheel and grinding fluid.

Actual wheel speed was 4600 fpm, work speed was 75 sfpm, and the experimental grinding fluid 95-70 was applied by the conventional overhead flood method; high volume and low velocity. In the roughening operation 0.020 to 0.025″ was removed from each surface, both flange and OD. An experimental No. 1182 (silicon carbide type) grinding wheel was used for this operation. It was dressed open and all 64 housings were rough-ground in 1½ minutes per piece without redressing the wheel. Approximately 0.008″ stock was left all over for finish grinding. For this operation the wheel was dressed medium open, and required redressing after every 20 pieces. The grinding time for this operation was ½ minute per piece, with surface finishes ranging from 10 to 15 micro-inch rms. No difficulty was experienced in either the roughing or finishing operation.

Conclusions. From the foregoing investigation it may be concluded that:

(1) Titanium can be ground on a production basis (internal, external, or surface), if the proper combination of grinding fluid and grinding wheel are used.

(2) A fluid of the high additive E.P. type is needed, capable of remaining effective at relatively high temperature.

(3) The grinding wheel speed need not be reduced to an undesirably low value.

(4) There is an optimum value of grinding wheel speed, work speed, traverse rate, and infeed which will give highest values of grinding ratio. These conditions are somewhat more critical for the grinding of titanium than for steel.

(5) Improved surface finish accompanies improved grinding ratios.

(6) The value of grinding ratio obtainable is affected by the hardness of the titanium being ground. This grinding ratio drops off rapidly if the hardness of the titanium exceeds a value of 39 to 40 Rockwell C.

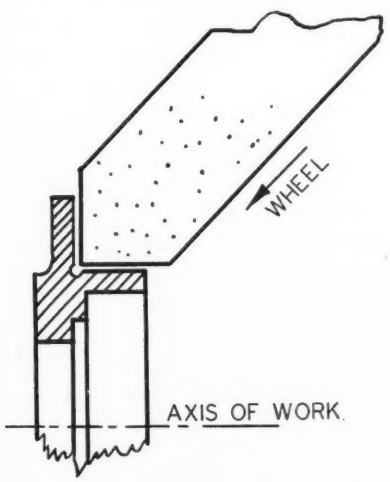


Fig. 10. Setup for simultaneously plunge grinding outside diameter, and facing flange of titanium bearing housing.

Summary. It has not been the purpose of this paper to exploit the development of a fluid for the grinding of titanium, but rather to emphasize the type of approach necessary to the solution of a specific grinding problem. In these times when we are presented with the problems of grinding metals such as titanium, zirconium, tantalum, columbium, uranium, and others, in addition to the many new high-temperature alloys, we may more and more find ourselves in need of "tailor made" grinding fluids if we are not to retard the fabrication of these metals. These fluids will not be found by the method of trial and error but will, of necessity, be developed through a methodical approach founded on a basic understanding of the specific problems involved.

ACKNOWLEDGEMENTS. The author wishes to express his appreciation to Dr. M. E. Merchant, Assistant Director of Research; and Mr. Hans Ernst, Director of Research, for their valuable assistance in developing the background the guiding the progress of this research; and Mr. W. A. Haggerty, Research Engineer, for his aid in carrying out the experimental work. The author also wishes to thank Mrs. C. S. Hannaford and Mrs. L. Gill for their aid in the preparation of the photographs and manuscript.

Current Literature

"Micro-Set" Manostat. Bulletin 655 illustrates both the external and internal construction of the Micro-Set Manostat, an instrument for regulating and holding a constant vacuum within 0.05 mm mercury pressure, and discusses such features as simplified adjustment, wide range, and exact reproduction of vacuum control. Specific applications in organic chemical, petroleum, physical and biological laboratories are also noted. (Precision Scientific Co., LE-11/6, 3737 W. Cortland St., Chicago 47, Ill.)

"Sunkote A" and "Sun 844X Grease." Bulletin 42 describes Sunkote A, a new anti-rust coating oil for improved low-cost protection of sheet and strip steel and ferrous castings; shows how it works and how to apply it. Bulletin 40 describes Sun 844X Grease, which can be used at temperatures up to 250 F., and includes a time-temperature chart showing the life of the product at various operating temperatures. (Sun Oil Co., LE-11/6, 1608 Walnut St., Phila. 3, Pa.)

Solvent Recovery. Booklet 4410D gives technical data on activated carbon, and describes the efficiency and economy of recovering solvent vapors in a variety of industries. (Carbide & Carbon Chemicals Co., LE-11/6, 30 E. 42nd St., New York 17, N. Y.)

"Molykote Type BR2." Bulletin 101 describes in detail Molykote Type BR, a general purpose (lithium-base) grease with extreme bearing pressure properties;

(Continued on p. 428)

Grease Lubrication Dispensing Equipment, Its Operation & Application

by L. R. McDonald*

A brief description is given of various grease lubrication dispensing equipment ranging from elementary methods of manual application involving grease cups and lever guns, to complex methods involving complete automatic centralized systems. Centralized lubrication reduces such items as down-time, safety hazards, manpower and lubricant waste.

Because of a desire to show no partiality to any one particular brand of grease lubrication dispensing equipment, a general description will be given of the equipment as a whole rather than a detailed description of any one brand.

The types of grease lubrication equipment available today are many and varied. They range from the simple grease cup for lubrication of a single bearing, to the complete automatic systems for lubrication of a thousand bearings. The old wooden paddle for the dispensing and application of grease was very often accompanied by match sticks, scale, scrap, or other foreign material that may have fallen into the exposed containers. In its place now are well-engineered mechanical devices capable of transferring the grease from the original sealed drum to the bearing with negligible exposure to outside contamination.

LEVER-TYPE GUNS. Lever-type grease guns are ideal for the lubrication of a few easily accessible points. These can be had in various capacities, the most common being 16, 20 and 30 ounces. Although not often realized, some of these guns are capable of developing 10,000 psi pressure, making it possible to force grease through fittings that may be rusted or corroded.

If the gun is equipped with a filler fitting, it can be filled in a matter of seconds by use of a filler pump. These pumps are available in portable and stationary models for use with original refinery containers from the 25 to 40 pound can up to 400 pound drums.

Volume and high-pressure bucket pumps, with hose assemblies and 25 to 40 pound reservoirs, are portable and have proven very successful in the manual lubrication of locomotive cranes, bulldozers, and tractors.

AIR-OPERATED DRUM PUMPS. These pumps have been engineered to meet a wide range of operating conditions and are manufactured in a variety of air inlet pressure to lubricant out-put pressure ratios. The manufacturers provide graphs and charts which make it relatively easy for the field man to select the correct pump for his application. These graphs and charts show the inlet air pressure in psi, the required cubic feet per minute of free air, the consistency of grease to be handled, and the output in psi pressure and pound per minute volume.

These drum pumps serve a variety of purposes. They can be used not only to transfer grease from one container to another, but also to transfer the grease from container to bearing. As an example of one of the combinations possible with a drum pump and auxiliary equipment, a system will be described which was set up for the lubrication of two cover carriers serving six rows of soaking pits at the Steubenville Works of the Wheeling Steel Corporation.

A small building at ground level contains the grease drum and drum pump. A small electric hoist running on an overhead "I" beam facilitates the transfer of the pump from one barrel of grease to another. An air-line lubricator and pressure regulator on the air inlet side of the pump provide lubrication of the air motor and a regulated air supply. The grease is piped from the discharge of the pump to the cover floor level. From here it is piped in a header along the length of the soaking pits. At three points along this header an outlet station is provided, and at each station a fifty foot length of hose is connected to the header through a high-pressure valve. At the other end of this hose is a control valve and coupler. By stopping a cover carrier near one of these stations, it is possible for the man lubricating the carrier to reach all bearing points. The air pressure is maintained on the pump at all times so that a flow of lubricant is obtained merely by operating the control valve at the end of any one of the hoses.

By the use of a similar type system, it is possible to set up greasing stations for such equipment as overhead cranes and bessemer and open hearth mold buggies.

CENTRALIZED LUBRICATION. Up to this time all of the equipment mentioned has necessitated the use of an oiler, or greaser as he may be called, to attach the coupler to each individual bearing. If he is conscientious and has a good memory, perhaps all of the bearings will be greased; if not, early bearing failure.

This brings to mind one of the most promising aspects of modern grease lubrication dispensing equipment: centralized lubrication. As defined in the Tentative Glossary of Lubrication, appearing in the July-August, 1954, issue of "Lubrication Engineering," centralized lubrication is "a system of lu-

*Wheeling Steel Corp., Steubenville Works, Steubenville, Ohio.

(This paper was sponsored by the ASLE Technical Committee on Lubrication Equipment, and presented at the ASLE 10th Annual Meeting, Chicago, April 14, 1955.)

brication in which the lubricant or lubricants for the bearing surfaces of a machine or group of machines are supplied from a central location."

The demands of modern production and the intricacies of modern machinery make centralized lubrication almost a must in certain applications. The need for such a system may stem from several factors, such as: (1) a lack of shut-down time for necessary lubrication; (2) a safety hazard; (3) a lack of available manpower; (4) a wasting of lubricants.

One of the most simple forms of centralized lubrication is one in which the individual bearing lubricant inlets are piped to a manifold, and a grease gun is used on the fittings attached to this manifold. Such a system is adequate for the lubrication of a few inaccessible bearings on a piece of equipment such as a small shear.

The next step is the proper selection and use of equipment designed and manufactured for the express purpose of centralized lubrication. These systems may be manual or automatic.

Manual System. In the manual system a hand-operated pump transfers the grease under pressure from the reservoir to the distributing blocks by means of pipe or tubing. From the distributing blocks it is piped to the bearing. The distributing blocks will vary in type and operation depending upon the manufacturer's system, but each serves the purpose of measuring the grease distributed to the bearing. One outstanding use to which these manual systems have been put is the lubrication of overhead cranes. Their use practically eliminates the danger to the greaser that can be realized in his lubricating such equipment. They are also used to lubricate operating units such as roller levelers, flash welders, presses, and large machining equipment.

Automatic System. The operation of the automatic centralized system is an elaboration of the manual system. The grease is transferred from a standard refinery container into a reservoir by means of an electric- or pneumatic-operated drum pump. From this reservoir the grease is pumped to the distributing blocks where a measured amount of grease is displaced and piped to the bearing.

An electrical timing device may be used to regulate the frequency of operation. By selection of the proper size of distributing blocks and adjustment of the timing cycle, a system can be installed to deliver the correct amount of lubricant to each bearing according to its load and speed requirements, regardless of its location, type, or size. There are different types of devices used to indicate whether or not the system is functioning properly. These may be in the form of signal lights or horns to show that the system has developed too much pressure, or that the pumping cycle is exceeding the usual operating time.

The use of a 24-hour constant recording chart is also advantageous. This gives a record of performance of the system and often aids in locating trouble in its early stages of development. For example: if an automatic system has been adjusted to perform its cycle in 10 minutes and has been doing so regularly, a reading of 15 minutes on the chart shows that something is delaying the cycle. Air may have been pumped in the lines due to an empty reservoir, a small leak, or pump wear. A little trouble-shooting along these lines may prevent the development of more serious trouble in the system.

Another device that will help to give more trouble-free operation of the system, and at the same time assure a clean lubricant in your bearings, is the strainer. A strainer installed in the fill-line to the reservoir will protect the pump, distributing blocks, and lubricated bearings from contaminants that may have found their way into the lubricant.

If some of the bearings fed by the system are ball or roller bearings, pressure relief fittings should be used. These fittings are available to relieve at various pressures. They will prevent the blowing of seals, will permit a flushing action by the lubricant, and will prevent overheating of the bearing from the addition of too much lubricant.

By the selection of the proper centralized system and auxiliaries, it is possible to lubricate practically any combination of bearings whether they are stationary or in motion. Swivel fittings make possible the lubrication of a journal making a fraction of a revolution or several hundred revolutions per minute. The wide variety of hoses available is another asset. There are low and high pressure hoses of oil-resistant materials and flexible metallic hoses for high-temperature applications.

In certain installations it is advantageous to mount the distributing blocks to a stationary part of the machine and run the bearing feed lines to the reciprocating, oscillating, or rotating members with hose. In other cases it is more satisfactory to mount the distributing blocks and feed lines as a solid unit on the moving member and to connect the stationary member with flexible lines.

Centralized grease systems lend themselves extremely well to the conditions encountered in the steel industry. For example, the hand lubrication of the many bearing points on the top of a blast furnace is very hazardous, since there is always the possibility of large quantities of gas being present. If a centralized system is used, the pumping station can be located at ground level and pressure lines can be run to the top of the furnace to feed the distributing blocks and ultimately each bearing.

A bessemer converter is also a hazardous place for manual lubrication of individual bearing points. With a centralized grease station located a safe distance from the handling of the molten metal, the greaser's duties are reduced to keeping his reservoir filled and checking his system for proper operation.

Centralized systems also do an excellent job in the grease lubrication of blooming mills, slabbing mills, hot strip mills, pickling lines, tandem mills, temper mills, shear lines, and various other pieces of equipment.

Advantages of Centralized Lubrication. Whether the centralized system be manual or automatic, there are certain apparent advantages. Less downtime for lubrication brings about increased production. The bearings are assured of a measured

amount of lubricant at a regulated interval of time and bearing life may thus be extended. It is possible to lubricate many bearings in the time that would be required to lubricate a single bearing by hand, and this results in fewer man-hours. It is possible to stay away from moving parts while lubricating machinery, thereby increasing the safety of operation.

If the installation of a centralized system is decided upon by the responsible party or parties, careful consideration should be given to the merits of all available systems, and that one should be chosen which best seems to adapt itself to the prevailing conditions.

COMMENTARY by E. J. Gesdorf (The Farval Corp.). Mr. McDonald makes some significant points in his paper, and perhaps the most important is the mention of the need for understanding the various types of dispensing equipment thoroughly so that the most suitable can be selected for a particular application. This brings up two of many points that could be discussed in connection with the importance of knowing thoroughly the various types of equipment that are being offered. First, my experience indicates that grease equipment that operates at high pressure, and at the same time works the lubricant excessively through small diameter ports, will in many instances cause bleeding or separation of the soap from the oil. When this occurs the equipment will plug with hard soap and fail. Second, it is my opinion that controlling lubricating system cycling by throttling pump delivery is questionable practice. It is a well-known fact that in any hydraulic system the lower the rate of flow the more exacting must be the fits. Extremely low pumping rates in lubricating systems offer minimum protection against wear and loose connections as the system's service life increases.

I was pleased to note the author's statement that single complete automatic grease systems are handling a thousand bearings or more. A short time ago I read a technical paper in which it was stated that the trend in industry is toward smaller systems and an example was cited of six finish stands in a hot strip mill each having an individual system. The author of that particular paper may have been speaking of a specific application, or the lubrication equipment he had in mind probably could not be satisfactorily applied to a large number of bearings over a wide area. Anyone can recognize the disadvantages in a separate system on each of six finish stands, as this is a complete reversal of the centralized idea and gets back to the old-fashioned method of lubrication by filling, servicing, and maintaining numerous pieces of equipment individually. There is no trend toward smaller systems; as modern centralized lubricating equipment, with adjustable time cycle and adjustable measuring valves, makes it possible to serve a great number of bearings scattered over considerable distance from one central point.

In describing the air-operated barrel pump with a pressure header line serving three flexible hose stations for greasing equipment within a 50′ range of each station, I was particularly interested in Mr. McDonald's final statement on this equipment: "If the oiler or greaser has a good memory, perhaps all of the bearings would be greased; if not, early bearing failure." In addition to the personal injury hazard, there are two undesirable features in this method of applying lubricants. One is the dependence on the human element, and the other is lack of control over the quantity of lubricant discharged to the bearings. This lack of control and dependence on the human element were the very items which lead to the development of the centralized lubricating system.

Mr. McDonald mentions briefly a centralized lubricating system installation on a bessemer converter, and I understand that this is a complete and unique installation. I wonder if he would be willing to discuss this application in a little more detail. Also, if he could give us some information on the savings in lubricant, maintenance, operating costs, and improved performance that have been brought about by centralized lubricating system installations at the Wheeling Steel Corporation.

AUTHOR'S CLOSURE. In answer to Mr. Gesdorf's question on the centralized grease lubrication system on the bessemer converter: The pumping station is located in a small, insulated building on the northeast corner of the vessel floor. It is an automatic unit electrically timed to distribute a measured amount of grease to the bearings at half-hour intervals. The main pressure lines are piped up a column and pass along the main structural beam over the iron and steel steadmans. From the main pressure lines, feed lines are piped in the structural steel work to the various manifolds which measure the amount of grease distributed to the bearings at each time-interval.

In the bessemer building approximately 100 bearing points are fed by the centralized system. This includes such points as the vessel trunnion bearings, the guides for the racks which tilt the vessels, the scrap hoist mechanisms, the self-centering and thrust bearings on the iron and steel steadmans, packing glands on hydraulic cylinders, and even the air blast valves. The system continues to the mixer building where an additional 90 bearing points are lubricated, 80 of these points being on the rollers in the race on which the 1500-ton capacity mixer tilts.

Because of the nature of operations of the bessemer, it would be virtually impossible to lubricate the majority of these bearings during operation. They would have to be lubricated during down-time, a practice which usually results in feast or famine operation.

Actual cost figures show the benefits that can be derived from a program concentrated on the proper application of lubricant-dispensing equipment and the lubricants themselves. The figures based on Steubenville Work's 1954 cost figures over 1953 show a significant reduction in the cost per ton of steel in lubrication, maintenance, and man hours. This included a decrease in the actual cost of lubricants during the same period.

With the results that can be obtained from its application, it seems inevitable that centralized lubrication will receive the recognition justly due it.

Cover Story

Machining With A Soluble Cutting Fluid. The photograph on the front cover of this issue shows a soluble cutting fluid in action. This fluid is a petroleum oil prepared with special ingredients that enable it to emulsify readily with large quantities of water. Applied to many machining operations, the soluble cutting fluid lubricates the cutting or grinding surface, while the added water removes excess heat.

In addition to the ability to cool and lubricate effectively however, the soluble cutting fluid is expected to possess other special properties. Continuous recirculation means that it must resist oxidation on a long-term basis; and metal particles must settle out of it quickly. It must resist foaming, prevent rusting of the machine tool and the workpiece, and contain nothing harmful to the operator's skin. Some of these products are transparent for a better view of the work. Some are fortified to serve under the more severe conditions imposed by tough new alloys and the high speeds and heavy loads of modern machinery.

Of course a soluble cutting fluid is not truly soluble in water, but it be-

(Continued on p. 432)

Some Unusual Conditions Encountered In The Lubrication Of Rolling Contact Bearings

by T. W. Morrison*

The lubrication of rolling bearings is not difficult. However, the operating conditions must be thoroughly understood in order to be sure that the proper lubricant is provided. Results of recent field experience and laboratory investigation emphasize the importance of viscosity in maintaining an adequate oil film at low speed and heavy load. Bearings subjected to unusual vibrating conditions while rotating at low speeds require special lubrication in order to prevent fretting corrosion between rolling elements and raceways. There has been considerable investigation into the fatigue life of rolling bearings. Variations in mineral oils have not been found to affect the endurance, but testing has shown certain of the synthetic fluids, at least, to cause a marked reduction in fatigue life.

This review of some of the unusual problems that have been encountered in the lubrication of rolling bearings is not intended to provide complete design data for these and similar applications. In most of the situations discussed, solutions have progressed to the point of providing satisfactory performance under a particular set of circumstances, but years of careful research will be required before there is complete understanding of all the factors involved. The problems cited serve to illustrate that as the variables of operation extend beyond the ranges now considered normal, bearing performance may be materially affected. For assurance of dependable operation it is essential that each bearing application be completely analyzed from the standpoint of applying the most suitable bearings with adequate lubrication for the conditions of service.

The lubrication of rolling bearings is not difficult under normal conditions. Only very small quantities of a suitable oil or grease are necessary. Wilcock and Booser[1] have shown that about 0.5 milligrams of oil per hour will provide satisfactory lubrication for a 6306 bearing under 160 lbs. radial load at 1800 r.p.m. Bearings as large as 6314 have been run at 1800 r.p.m. in our Laboratory under 1000 lbs. radial load with as little as 1 drop of oil every four hours, as reported by H. Styri.[2]

The lubrication requirements for operating conditions must be thoroughly understood. Even though the bearings may be completely immersed in a bath of oil, adequate lubrication is not assured. The oil which actually does the work is that maintained between the surfaces under load. With very slow speed and heavy load it is not possible to preserve a film between the rollers and races unless the viscosity is extremely high, because there is time for the oil to be squeezed out ahead of the rollers as they advance. If the speed were increased under such conditions, a velocity would be reached at which there would not be time for the oil to escape from between the surfaces and a film would be maintained. Similarly, if the speed were kept constant, a film could be provided between the load surfaces by increasing the oil viscosity to the point at which there would not be time for the oil to be squeezed out ahead of the rollers.

Provided rolling bearings are protected from moisture and dirt, are properly mounted, and are well lubricated, the only factor limiting their useful life is a fatigue failure of one of the component parts. The fatigue phenomenon is the result of

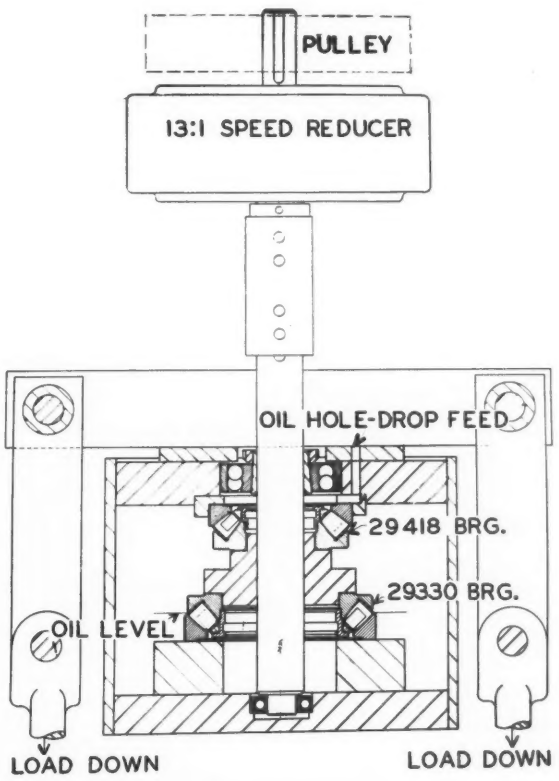


Fig. 1. Test set-up used to investigate oil viscosities required at low speeds and heavy loads.

*SKF Industries, Inc., Philadelphia, Pa.

(This paper was sponsored by the ASLE Technical Committee on Bearings & Bearing Lubrication, and presented at the ASLE 10th Annual Meeting, Chicago, April 14, 1955.)

cyclic loading and unloading of the parts and is evidenced by flaking of the material, which starts as a small crack and develops into a spalled area. The number of cycles that will be attained by a bearing before fatigue failure takes place is decreased appreciably as the stress increases. In order to keep the unit stress as low as possible, the geometry of the load-carrying surfaces is held to very close limits, and surface finishes are maintained to the highest commercial standards so that the load will be distributed over the largest area practicable.

Even with rolling bearings, there is a small amount of sliding under load because of elastic deformation of the load-carrying surfaces. Without sufficient lubrication to prevent serious metal-to-metal contact of the surfaces, this sliding can cause serious damage resulting in premature bearing failure.

The most positive lubrication for the majority of bearing applications is provided by oil. Mineral oils are principally used since these are rather uniform in their characteristics, and can usually be selected with regard to a suitable viscosity only. Under normal speeds of operation a wide range of viscosities can be tolerated. As the speed increases, lighter viscosities must be used and the quantity of oil controlled to prevent excessive churning and accompanying high temperature, which may exceed safe limits for both bearing and lubricant. Should the viscosity be too light there will also be a rise in temperature due to the metal-to-metal contact of the load-carrying surfaces. If operation is continued under these conditions the temperatures will become great enough to temper the bearing components, resulting in early failure and the characteristic discoloration of the surfaces generally associated with inadequate lubrication.

Operation at Very Low Speed & Heavy Load. As the speed decreases, heavier viscosities must be used under heavy load in order to prevent serious metal-to-metal contact of the surfaces and wear from the relative sliding. At very low speed there is no measurable temperature rise, even under heavy load and with an oil viscosity that is not adequate to provide necessary separation of the rolling surfaces. First visible evidence of breaking through the oil film under such conditions is a glazing or burnishing of the surfaces.

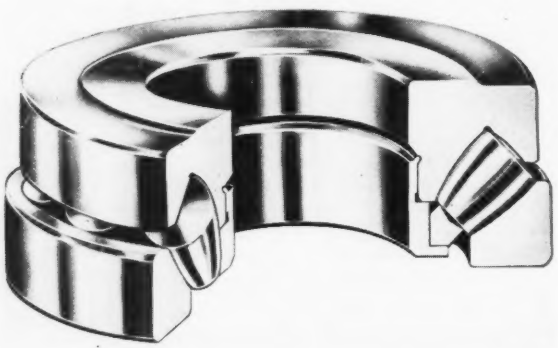


Fig. 2. Cut-away view of a spherical roller thrust bearing.

Fig. 3. Typical surface of a 29330 spherical roller thrust bearing outer race, after operation with adequate lubrication to prevent glazing.

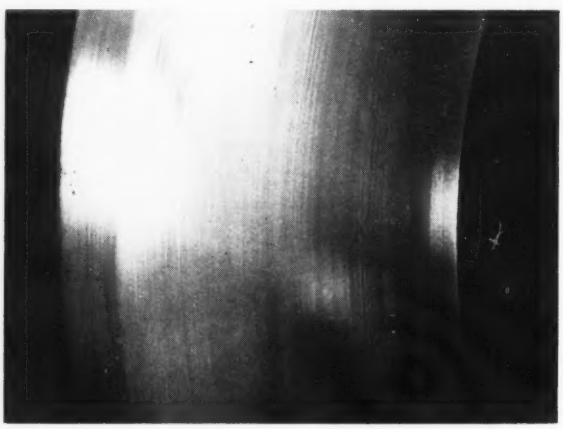


Fig. 4. Glazed surface of a 29330 spherical roller thrust bearing outer race, typical of operation at low speed with an oil film inadequate to prevent the polishing of the surfaces resulting from metal-to-metal contact.

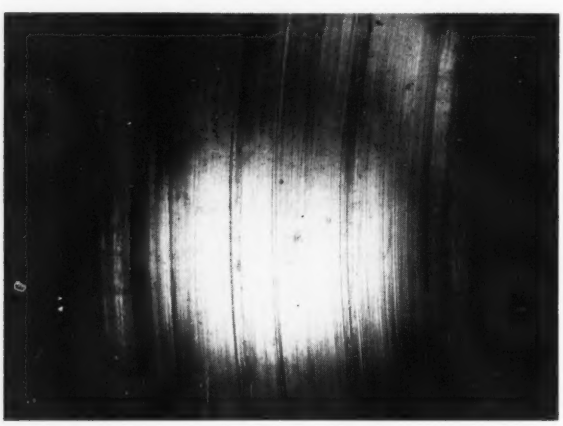


Fig. 5. Glazed and grooved surface of a 29330 spherical roller thrust bearing outer race, resulting from operation with an oil film completely inadequate to prevent severe wearing of the surfaces resulting from metal-to-metal contact.

To study the lubricating requirements at very slow speed and under heavy load, tests are being conducted in our Laboratory. The setup shown in Fig. 1 is being used to investigate oils for spherical roller thrust bearings. A cutaway view of a bearing of this type is shown in Fig. 2. The spherical-shaped race shown on the bottom in the figure is identified as the outer race of such a bearing. A 90 mm. (29418) and a 150 mm. bore (29330) bearing are mounted opposed for testing, as shown in Fig. 1 so that the thrust load is carried through each bearing. Both bearings are lubricated with the same oil, the top one (29418) by drop feed, and the bottom one (29330) with a fixed level. Radial bearings are mounted at top and bottom of the shaft to insure that the tilting forces resulting from the belt pull will not affect the load distribution of the test bearings.

A normal-appearing surface of a spherical roller thrust bearing outer race operated with an oil viscosity capable of preventing any visible evidence of metal-to-metal contact is shown in Fig. 3.

A typical glazed surface of the outer race from such a bearing, produced as the result of operating at slow speed and heavy load with an oil viscosity inadequate to provide necessary separation of the parts, is shown in Fig. 4. With even less favorable lubrication than provided for the race of Fig. 4 there will be, in addition to the glazing, severe wearing of the load-carrying surfaces which usually takes place in the form of circumferential grooves as shown in Fig. 5. Such a condition of grooving greatly reduces the area of contact and causes much higher stresses than obtained in an undamaged bearing, resulting in appreciably shorter fatigue life.

Operating conditions for the bearings from which the outers of Figs. 3 to 5 inclusive were obtained are tabulated in Table I. In addition to the work on thrust bearings, tests have been conducted with radial bearings and show similar results.

It is recognized that the oil viscosity required to maintain an oil film is dependent upon the relative surface velocities and pressure at the load-carrying surfaces, irrespective of bearing size or type, and the tests are being continued to establish this fundamental information.

Fretting Corrosion in Rotating Bearings. Another illustration of the harmful effects resulting from not maintaining an adequate oil film in rolling bearings is found in the applications in which fretting corrosion or friction oxidation is obtained between the balls or rollers and race grooves. This type of damage has been recognized for some time in bearings that either do not rotate in the presence of vibration, or oscillate only a few degrees in their service; the difficulty being to maintain an oil film between the load-carrying surfaces.

Friction oxidation has also been found recently in bearings that have been rotating, but at a speed too slow to maintain an oil film with the lubricants used and the service conditions encountered. The application involved 6204 and 6205 size prelubricated deep-groove ball bearings installed on the back and front bottom rolls, respectively, of textile spinning machines. A portion of the textile ma-

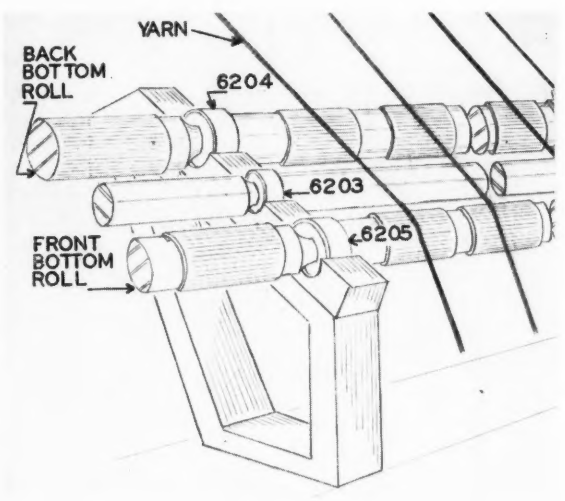


Fig. 6. Portion of textile spinning machine showing mounting of prelubricated deep groove ball bearings on bottom rolls.

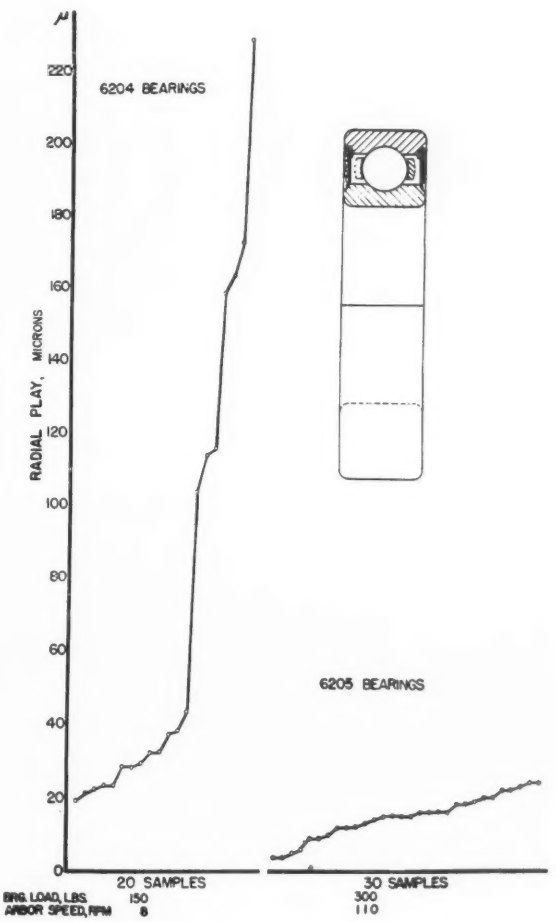


Fig. 7. Internal radial clearance of prelubricated deep groove ball bearing after approximately 18 months service in the initial installation on the bottom rolls of textile spinning machines.

chine, presenting the bearing mounting, is illustrated in Fig. 6. The bearings are subjected to the rather appreciable vibration of the machine resulting from the spinning spindles, about 230 in number, which are mounted beneath the rolls to spin the yarn and receive the thread. These spindles operate at speeds of around 10,000 r.p.m. while carrying packages of thread weighing approximately 12 ounces when full, with various degrees of unbalance. The front roll bearings rotate at about 110 r.p.m. under 300 lbs. radial load and have given no trouble from friction oxidation. The back roll bearings operate at about 8 r.p.m. under 150 lbs. radial load and are found to develop various degrees of iron oxide as the result of friction oxidation. Once formed the oxide acts as a lapping compound, and wears the balls and raceways so that the looseness is greatly increased. Radial looseness values of typical front and back roll bearings after approximately eighteen months' operation in the initial installation are shown in Fig. 7.

Photographs of the inner race grooves of representative bearings from front and back rolls are shown on Figs. 8 and 9.

The ball groove of the 6204 inner shown in Fig. 8 has a highly glazed apppearance, which is a result of the operation at slow speed without adequate lubrication and the lapping from the iron oxide produced by the fretting corrosion. A band of oxidation corrosion can be seen around the 6204 inner groove. To permit examining the groove surface in more detail, a photomicrograph taken at 50 magnification is shown in Fig. 8b. The glazed,

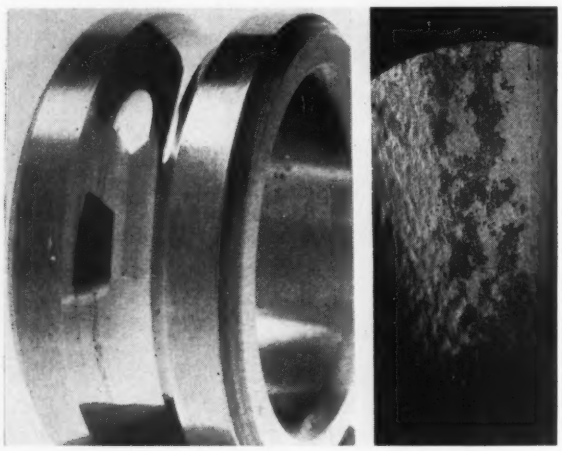


Fig. 8. Inner race from 6204 ball bearing showing effects of friction oxidation in ball groove resulting from inadequate lubrication for vibrating conditions at low speed; **Fig. 8a** (left) 4X magnification; **Fig. 8b** (right) 50X magnification.

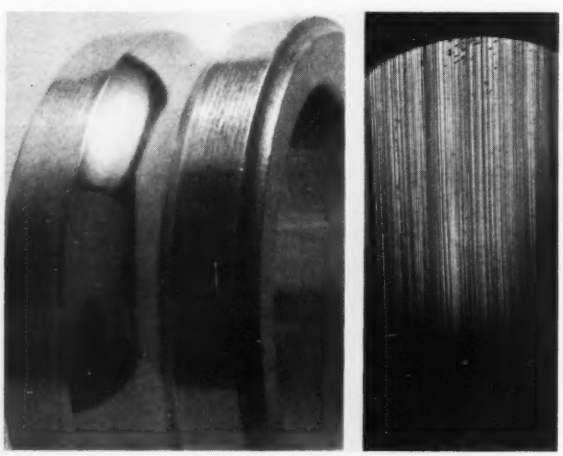


Fig. 9. Inner race from 6205 ball bearing showing typical ball groove surface after performance with satisfactory lubrication; **Fig. 9a** (left) 4X magnification; **Fig. 9b** (right) 50X magnification.

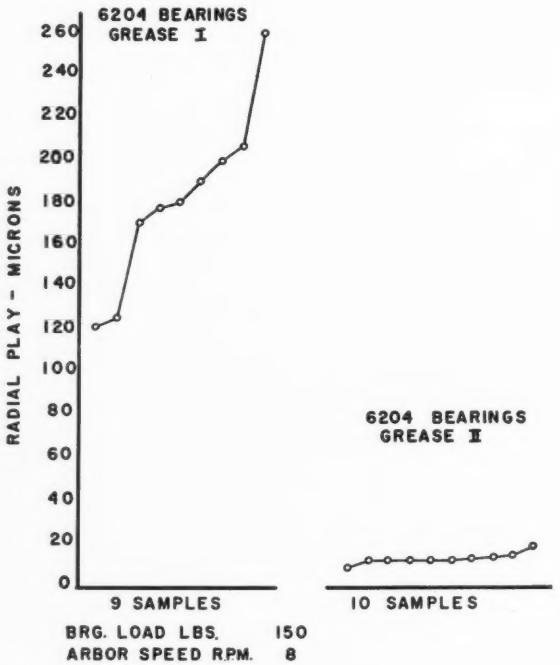


Fig. 10. Internal radial clearance of 6204 prelubricated deep groove ball bearings after approximately 18 months service with test greases on the bottom rolls of textile spinning machines.

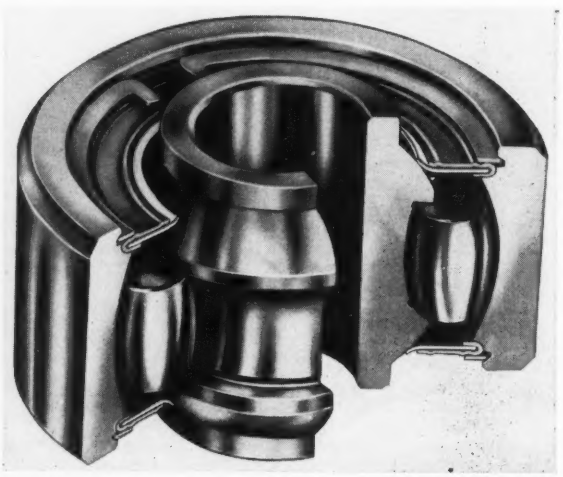


Fig. 11. Cut-away view of DSRP control rod bearing.

lapped surface and the band of oxidation corrosion resulting from the friction oxidation can be seen. The original polishing lines of this race have been completely removed as a result of the lapping from the iron oxide. The original polishing lines of the 6205 inner are clearly evident in the photomicrograph of this race shown in Fig. 9b.

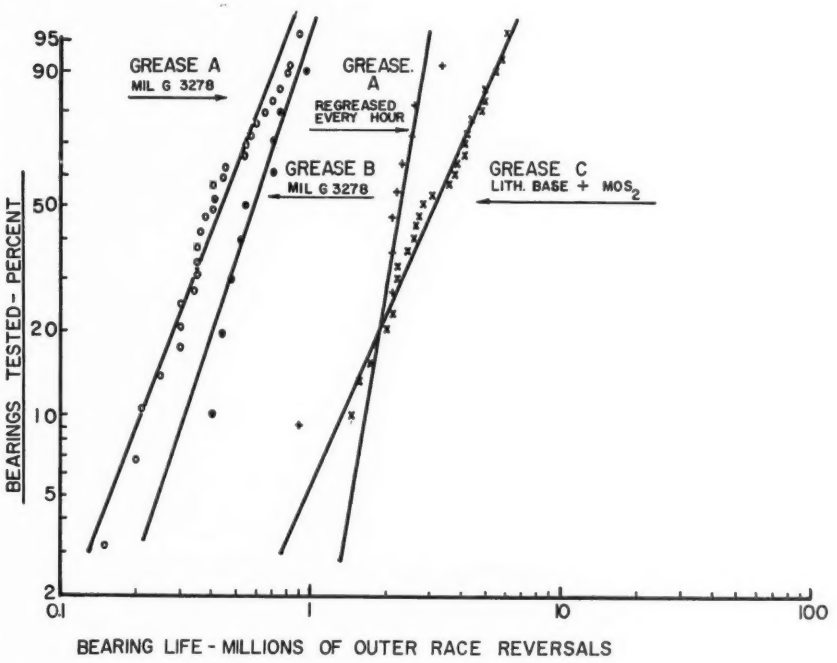


Fig. 12. Endurance of DSRP bearings with various conditions of lubrication. (Radial load, 3500 lbs.; 260 outer race reversals per minute; 90° total oscillation.)

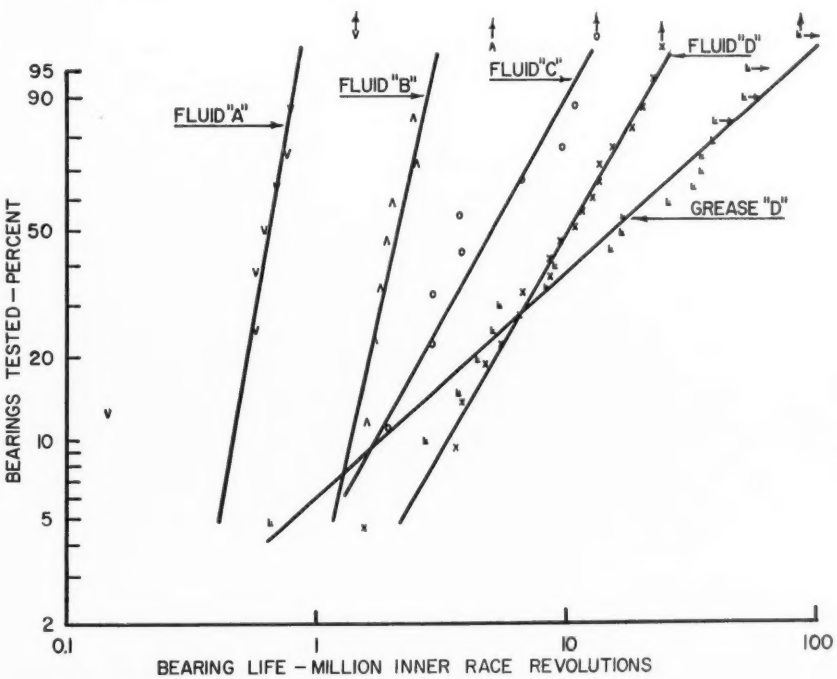


Fig. 13. Bearing fatigue life obtained with several synthetic hydraulic fluids (A to D inc.), and with a sodium-calcium soap base grease (D) for comparison.

Different lubricants are presently being investigated for use in the 6204 bearings, and it is believed that one or more has been obtained which will provide satisfactory lubrication under the operating conditions.

Results with two greases that have been tested are shown in Fig. 10. Grease I has provided no improvement but with Grease II there has been no wear and, therefore, no increase in the radial looseness of the bearings after about 18 months' operation.

Endurance Affected By Lubricant — Oscillating Motion. The possibility of variations in mineral oils affecting the endurance of rolling bearings has not been studied, except under the conditions already discussed where the viscosity was not adequate to prevent serious metal-to-metal contact. Such an investigation has not seemed necessary since many different makes and viscosities of oils have been used in service and in laboratory testing without evidence of deleterious effects.

However, certain synthetic fluids have been found to markedly reduce the fatigue life of rolling bearings, particularly under relatively heavy loads. One instance was with airframe control rod bearings lubricated with greases meeting MIL-G-3278 specification, which utilize synthetic fluids to attain the low temperature characteristics expected of such products. These bearings are of a new design designated as DSRP and were tested in our Laboratory under contract No. AF33(038)18562 with the U. S. Air Force. The DSRP bearings are self-aligning, since they have a single row of barrel-shaped rollers confined in a spherical outer race, and have contacting seals on each side, as shown in Fig. 11.

The purpose of the testing was to determine the load-life relationship for oscillating motion of the outer race. The bearing outer races were oscillated through a total angle of 90° at 260 reversals per minute (2 reversals equal 1 cycle).

For the original testing the bearings were lubricated with one application of a grease meeting MIL-G-3278 specification. Grease of this type is required in prelubricated bearings for such applications in order to permit low torque at low temperature. The endurance of the first lot tested was very poor. There was, of course, an ample supply of lubricant within the bearings, but ensuing investigations into the reason for the early failures revealed that better life was obtained by occasionally pushing fresh grease into the load zone.

A comparison of the fatigue life obtained under 3500 lbs. radial load, with one application of Grease A meeting MIL-G-3278 specification, and with small quantities of the same grease added every hour, is shown in Fig. 12.

The fatigue data of Fig. 12 are presented in a form that has been termed a "Weibull plot." This method of plotting data is based on a statistical theory of strength of materials as developed by W. Weibull.[3] The plot of bearing fatigue data follows the equation:[4]

$$\text{Log } 1/S = KL^e$$

where S = the probability of survival (1 — % of failed brgs.); L = life in million revolutions; K = constant for the brg. type; and e = dispersion exponent.

For plotting, this equation is used in the form

$$\log \log 1/1 - S' = \log KL^e$$

in which S' is the probability of failure. The ordinate is plotted as S' (percentage of bearings tested) on a scale laid out according to log log $1/1 - S'$, and the life, L, is plotted on a logarithmic scale. The ordinate scale ranges from 2% to 95% and the abscissa scale ranges through 3 log cycles in the present charts.

The best-fitting straight line drawn through the plotted points indicates the expected life of any desired percentage of bearings based on the data presented. The best-fitting line for any number of bearings tested can be calculated, but in this paper the curves have been drawn in by eye. The life in Fig. 12 is plotted in million outer race reversals instead of revolutions.

From Fig. 12 it is seen that the rating life[5] (life at which 10% of the bearings failed) was slightly less than 2 million reversals with Grease A added every hour, as compared with approximately 0.2 million reversals with one application of the same grease. As a result of this evidence that the lubricant was having an effect on the endurance of the bearings, several other greases were tried in an effort to obtain one which would give satisfactory life with one application. Grease B, also meeting MIL-G-3278, was first substituted but this did not increase the life appreciably over that obtained with the initial quantity of Grease A, as shown by Fig. 12. Grease C, which does not meet MIL-G-3278 specification, was the best obtained in the limited search and the lives of thirty bearings lubricated with this are shown in Fig. 12. The rating life is over 1 million reversals. Grease C has a lithium soap base and contains molybdenum disulphide and mineral oil.

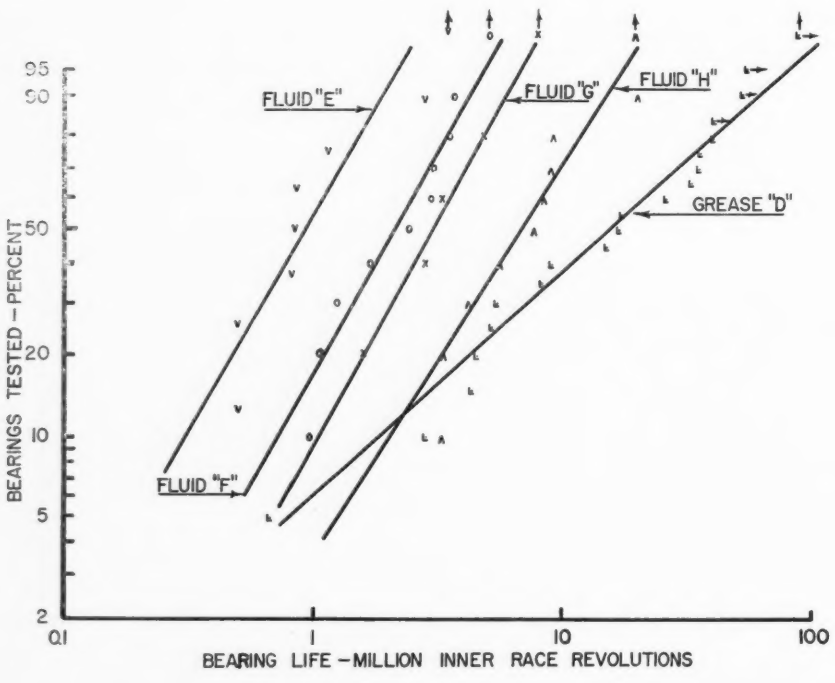


Fig. 14. Bearing fatigue life obtained with several types of fluids, and with Grease D. Key: Fluid E, non-leaded gasoline type; Fluid F, water soluble grinding compound; Fluid G, glycerine; Fluid H, sulphonated hydrocarbon cutting oil. (1205 bearings; 1070 lbs. radial load; 3000 r.p.m. of inner race.)

At the present time it is not known whether the low life obtained with the greases meeting specification MIL-G-3278 was due to the low viscosity of the synthetic fluids which these contain, or to some other factor. Similarly, it is not known whether the molybdenum disulphide was responsible for the improved life obtained with Grease C or whether any grease with a suitable mineral oil would give comparable results under the same conditions.

Endurance Affected By Lubricant—Rotating Motion. Another instance of the effect of the lubri-

Table I.

Fig.	EP Additive Base In Mineral Oil Used For Lubrication	Oil Viscosity At Operating Temp.	Running Time Hours	Surface Condition
3*	Lead Soap	7000 SSU	449	Normal
4*	None	1000 SSU	276	Glazed
5*	Lead Soap	270 SSU	705	Glazed & Grooved

*Arbor Speed RPM, 1.25; Thrust Load Lbs., 51,600.

cant on fatigue life of rolling bearings has been found with the so-called synthetic hydraulic fluids. In many cases these fluids provide lubrication for the bearings of circulating pumps. Where the bearings have been relatively heavily loaded, extremely early fatigue failures have been encountered. To investigate this problem endurance tests on bearings have been run in our Laboratory, with the fluids being investigated as lubricants. 1205 self-aligning ball bearings were used to evaluate the materials; a number of the bearings being run to fatigue failure with each fluid tested. The bearings were operated under a radial load of 1070 lbs. at 3000 r.p.m. The fluids were confined in reservoirs in the test bearing housings. A volume of 3 c.c. brought the liquid level to the center line of the lowest ball when the bearings were not rotating. There was no fluid added to the initial amount placed in the reservoirs during the life of the bearings.

Lives obtained with four hydraulic fluids tested, A to D inclusive, are plotted in Fig. 13. For comparison lives are also shown for a group of bearings run with Grease D, a sodium-calcium soap base grease containing a hydrocarbon oil.

It will be seen that there were considerable differences in the rating lives obtained with the various fluids. These differences are significant enough to eliminate the possibility of their being the result of normal spread expected in bearing life. It is evident that the inherent characteristics of the materials affected the bearing endurance to the degree indicated. Complete analyses of the several products are not available to determine which factors affect the endurance, since most of this information is treated as confidential by the organizations producing the materials tested.

For the added interest the lives obtained with a number of the 1205 bearings lubricated with nonleaded gasoline (E), a water soluble grinding compound (F), glycerine (G), and a cutting oil (H), are shown in Fig. 14. The curve for Grease D is repeated in Fig. 14 for ready comparison.

BIBLIOGRAPHY

(1) E. R. Booser & D. F. Wilcock: "Minimum Oil Requirements of Ball Bearings." Sponsored by the ASLE Technical Committee on Bearing Lubrication, and presented at the ASLE 7th Annual Meeting, April 9, 1952.

(2) H. Styri: "Friction Torque in Ball & Roller Bearings." Contributed by the Special Committee on Lubrication, and presented at the ASME Annual Meeting, Dec. 2-6, 1940.

(3) W. Weibull: "A statistical Theory of the Strength of Materials." IVA Handlingar (Royal Swedish Academy of Engineering Sciences, Proceedings), Nr. 151, 1939.

(4) G. Lundberg & A. Palmgren: "Dynamic Capacity of Rolling Bearings." Acta Polytechnica 7(1947), Mechanical Engineering Series, Vol. 1, Nr. 3.

(5) AFBMA Standards: "Method of Evaluating Load Ratings of Annular Ball Bearings."

ACKNOWLEDGEMENTS. We take this opportunity to compliment the United States Air Force on their sound approach to the problems encountered with fatigue of control rod bearings, by the study sponsored under Contract No. AF33 (038) 18562. We appreciate permission to present in this article a portion of the data collected during the investigation.

Lubrication Abstracts

(This is the second in a series of abstracts of translations of Foreign articles on lubrication, by Henry Brutcher. Copies of the full translations are available, at the indicated prices, by writing Mr. Brutcher at P. O. Box 157, Altadena, Calif.)

Effect of Die Angle, Lubricant & Drawing Speed on Power Requirements in Drawing Small-Gage Steel Wire, Especially in Multiple Drawing Machines, by A. Pomp & H. Heckel; "Mitteilungen K. W. Institut Eisenforschung," Vol. 17, 1935; 40 figs., 9 tables, 12,600 words. Critical review of literature. Testing program. Test equipment, materials, and procedure. Wear of drawing dies. Evaluation of test data. Effect of lubricant (soap, lees liquor, and rape oil) upon pull required, outward appearance, and finish of wire. Influence of other factors. (Order No. 307, Price $12.60)

Fatigue Tests of Steel Wire Under Alternating Tensile Stress, by A. Pomp & M. Hempel; "Mitteilungen K. W. Institut Eisenforschung," Vol. 19 & 20, 1937-38; 3 figs., 1,500-word abstract. Effect of processing of wire on fatigue limit under stress from zero to maximum. Analysis, heat treatment, and working. Effect of corrosive liquid (city water) and additional cold work by bending and twisting. Effect of reduction in pass. (Order No. 729, Price $1.50)

Influence of Surface Activity of Liquid Medium Upon Cutting Processes & Machinability of Metals, by N. A. Pleteneva & P. A. Rebinder; "Doklady Akademii Nauk SSSR," Vol. 62, 1948, pp. 501-504; 2 figs., 2,100 words. Study of the kinetics of drilling and the role played by active cutting fluids. Effect of additions of surface-active substances to hydrocarbon liquids upon specific cutting work. Data on nature of effect of cutting fluid within two distinct ranges: Range of absorption-conditioned reduction of work of deformation and range of reduction of external friction. Conclusions drawn from results as to evaluation of oiliness of active cutting fluids. Better surface finishes and continuous instead of broken chips are obtained through optimum additions of surface-active substances to cutting fluid. (Order No. 2365, Price $4.20).

Energy Balance of the Metal-Cutting Process, by G. I. Epifanov & P. A. Rebinder; "Doklady Akademii Nauk SSSR," Vol. 66, 1949, pp. 653-656; 2 figs., 1 table, 1,600 words. Experimental study of energy balance of the process of cutting metals, with special reference to portion of cutting work absorbed by plastically deformed chips, and to influence exerted by surface-

(Continued on p. 427)

Evaluation Of Lubricating Grease Compatibility

by A. L. McClellan & S. R. Calish, Jr.*

The mixing of two or more lubricating greases of different soap bases may occur in service and may result in impaired performance. Examples of such incompatibility encountered in service are described. Laboratory evaluation of mixtures of greases prepared by stirring them together produced some unexpected effects upon consistency, dropping point, and bearing performance; and heating the mixed greases intensified these effects. ASTM dropping point and consistency measurements are given to illustrate the changes. Laboratory performance tests demonstrated that mixing can impair the performance of greases, thus corroborating the field observations.

Greases are said to be incompatible if the physical properties and service performance of their mixtures are poorer than would be expected from a linear relationship. In our extensive field experience with both automotive and industrial greases we have observed a few cases of impaired service performance resulting from the mixing of two or more greases of different thickener types. Lack of compatibility appeared to be the explanation as service difficulties will result if the properties of the incompatible mixtures are inadequate for the service requirements. This paper describes service difficulties due to lack of grease compatibility and the subsequent laboratory investigation of this phenomenon. To predict grease compatibility, laboratory evaluation procedures which correlate with service performance must be available. Correlation with service was achieved by conducting laboratory performance tests on greases which had proved to be incompatible in the field.

Grease Mixing in Service. Incompatible grease mixtures were encountered in a variety of different applications. Difficulty was experienced with automotive wheel bearing greases, industrial multipurpose greases, cannery greases, and steel mill greases. In some instances the greases were hand-packed into antifriction bearings, while in others large centralized dispensing systems were involved. In all cases the evidence of incompatibility was excessive fluidity soon after mixing.

The simplest example of incompatibility seen in the field occurred in a service station inspection of wheel bearings. In this case, a new car had been inspected; and the attendant, following the inspection of wheel bearings, spread a different grease on the bearings to insure adequate lubrication. Evidence of grease fluidity was soon noticed when a soft grease mixture streaked the outside of the front wheels. The error was rectified before real damage occurred. Subsequent analysis of the soft grease mixture showed both calcium and sodium soaps to be present.

Another instance of incompatibility resulted from the addition of a mixed, lithium-calcium base, multipurpose grease to the barium soap product normally used in the large, antifriction pinion thrust bearings of a ball crusher in a cement plant. It is, of course, not possible under normal operating conditions to clean such bearings when changing lubricants. The grease mixture operated satisfactorily for some time but finally flowed out onto the floor. The consistency of the resulting soft grease had no resemblance to that of either of the original products.

Trouble was encountered in a cannery when greases of different soap bases were tried one after another by plant personnel to solve a lubrication problem. First, a calcium soap grease was used. It was not sufficiently heat resistant for the application involved. Then, a sodium soap grease was used. It worked well until the night crew hosed down all the machinery and washed the grease from exposed bearings. Finally, a lithium base lubricant was tried and appeared to be unsatisfactory because fluid grease flowed from critical bearings. Analysis of the fluid lubricant showed it to contain almost equal proportions of calcium, sodium, and lithium greases. When the bearings were adequately cleaned, the lithium soap grease provided excellent lubrication.

A still more complex mixture leading to extreme grease fluidity was found in a steel mill. During the course of a service test of a new, extreme

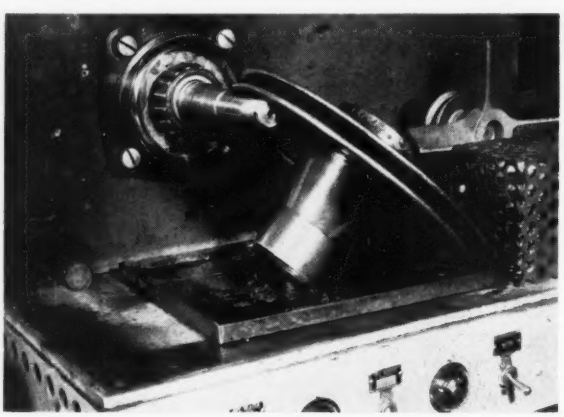


Fig. 1. Mixture of calcium and sodium base greases; ASTM grease leakage tester operated at 180 F.

*California Research Corp., Richmond Lab., 576 Standard Ave., Richmond 1, Calif.

(This paper was sponsored by the ASLE Technical Committee on Physical Properties of Lubricants, and presented at the ASLE 10th Annual Meeting, Chicago, April 15, 1955.)

Table I. Physical properties of some binary combinations of commercial greases. Key: (1) Penetration, after 24 hours, of grease which had received no working other than that of mixing; (2) Penetration after 60 strokes in the ASTM worker.

Soap Composition, weight per cent		ASTM Penetration		ASTM Dropping Point, °F
Calcium	Sodium	P_0 (1)	P_{60} (2)	
100	-	188	231	216
80	20	208	250	206
60	40	225	273	195
40	60	236	283	214
20	80	250	290	329
-	100	251	290	368
Barium	Lithium-Calcium			
100	-	296	349	360
80	20	114	265	301
60	40	150	273	249
40	60	199	283	290
20	80	238	297	328
-	100	251	290	368

pressure, steel mill grease, the test lubricant was introduced into the distributing system pump after flushing out the main distribution lines. When this lithium-calcium product was mixed with the grease already in the smaller distribution lines and bearings, the resulting mixture lost all semblance of grease structure and was fluid even at room temperature. Subsequent analysis showed lead, sodium, and aluminum to be present in the fluid mixture in addition to lithium and calcium. Then it was learned that previous mixing had occurred in the system because of a mistake by an oiler. A calcium-lead base grease used in other parts of the mill had been inadvertently added to the sodium-aluminum grease ordinarily used in the test location.

After experiencing these field problems, laboratory work was begun to establish the magnitudes of the effects of mixing in several mixed thickener, grease systems.

Sodium-Calcium Binary System. The first grease system studied in this investigation was the simplest encountered in the field, the binary mixture of sodium and calcium wheel bearing greases. This type of mixture has been discussed by Ehrlich and Sayles (NLGI Spokesman, February 1954). They show the serious difficulties which can result from a lack of compatibility. In addition to a modified procedure employed with the ASTM Grease Leakage Tester (ASTM Method D 1263-53T), ASTM dropping points and penetrations were obtained with various mixtures of the two greases. The data for the physical tests are shown in the first half of Table I, while the results of the laboratory performance test for the 50-50 mixture are shown in Fig. 1. The latter test was made in the ASTM Grease Leakage Tester at 180 F. for only 80 minutes. The photograph shows the complete lubricant failure that resulted from incompatibility.

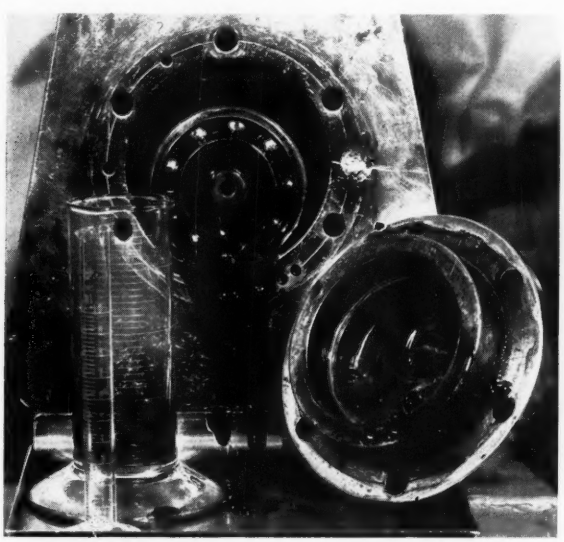


Fig. 2. Mixture of barium and lithium-calcium base greases; Antifriction Bearing Machine operated at 250 F.

Table II. Physical properties of mixed commercial greases (lithium stearate, sodium stearate, hydrated calcium tallowate). Key: (1) Penetration, after 24 hours, of grease which had received no working other than that of mixing; (2) Penetration after 60 strokes in the ASTM worker; (3) Unworked grease was so soft that P_{∞} was not measured.

Soap Composition, weight per cent			Commercial Greases Cold Mixed			Commercial Greases Cold Mixed Stirred at 400° F		
			ASTM Penetration		ASTM Dropping Point, °F	ASTM Penetration		ASTM Dropping Point, °F
Lithium	Sodium	Calcium	P_0 (1)	P_{60} (2)		P_0 (1)	P_{60} (2)	
100	-	-	227	261	394	121	183	378
80	20	-	237	278	354	118	187	364
80	10	10	205	248	368	223	296	354
80	-	20	216	265	362	150	197	362
60	40	-	246	301	315	106	170	309
60	20	20	225	277	312	195	261	320
60	-	40	231	284	297	161	302	331
40	60	-	288	325	332	326	400+	276
40	40	20	248	311	266	156	222	291
40	20	40	229	296	276	185	265	279
40	-	60	245	298	266	173	265	293
33	33	34	241	307	262	177	241	268
20	80	-	265	316	307	160	229	294
20	60	20	269	327	261	191	307	275
20	40	40	248	304	235	223	332	272
20	20	60	227	290	250	345	374	239
20	-	80	261	305	237	400+	(3)	234
10	80	10	288	332	339	361	400+	252
10	10	80	253	300	215	400+	(3)	177
-	100	-	278	323	352	189	338	348
-	80	20	290	340	336	278	400+	234
-	60	40	271	325	211	242	351	287
-	40	60	256	313	192	248	292	233
-	20	80	265	305	197	400+	(3)	178
-	-	100	273	302	209	400+	(3)	180

Barium, Lithium-Calcium Mixture. The last half of Table I shows data for similar physical tests on mixtures of the two greases used in the cement plant. This is a more complex two-grease system as three metal compounds are involved. The data show consistency and dropping point fluctuations which are not predictable from the characteristics of the individual greases. The marked lowering of the dropping point for the 60 barium 40 lithium-calcium mixture is noteworthy.

Performance properties of the grease mixtures were evaluated in a test machine employing two opposed, thrust loaded, deep groove ball bearings equipped with suitable means of controlling bearing temperature. This device, which we designed and call the Antifriction Bearing Machine, simulates the overlubricated conditions found in machinery lubricated from automatic, centralized, dispensing systems or too frequent, hand gun lubrication. In a test in the Antifriction Bearing Machine at 250 F., a 50-50 mixture of the greases proved to be quite unstable, as shown in Fig. 2, while similar tests on the separate greases showed each to be stable. The ex-

cessive fluidity illustrated would be expected from the dropping points given in Table I and checks the field experience reported above.

Lithium, Sodium, Calcium Ternary System. The three commercial greases which were used in the cannery were cold blended in the laboratory in various proportions, as shown in Table II. Consistency and dropping point determinations were made with each of the 25 samples prepared, and the data are also given in the table. In addition to cold blending, samples of the blends were stirred at 400 F., cooled to room temperature, and then tested. The properties of the mixed greases can be illustrated by means of three dimensional models, such as those in Fig. 3. The composition of any three-component mixture is represented by a point on the triangular base. The magnitude of the property is denoted by the height of a rod located at the point showing composition. The irregular plaster surface passing through the tops of all the rods gives an over-all picture of the effect of mixture composition on the depicted property. Levels of constant properties are shown by the contour lines. When the greases were simply cold mixed, the resulting values for penetration and dropping point, as shown by the surfaces of Fig. 3, were more regular than the values for the samples after they were heated to 400 F. The latter data are represented by the surfaces shown in Fig. 4. To provide the best view, the consistency models are rotated with respect to the dropping point models.

The dropping point surface of Fig. 3 for the cold mixed samples does not show the bulge, about half way between the 100% calcium apex and the 100% sodium grease that appears in Fig. 4; but in other respects the plots are similar. The consistency surfaces, however, differ widely, as shown in the upper photographs of Figs.

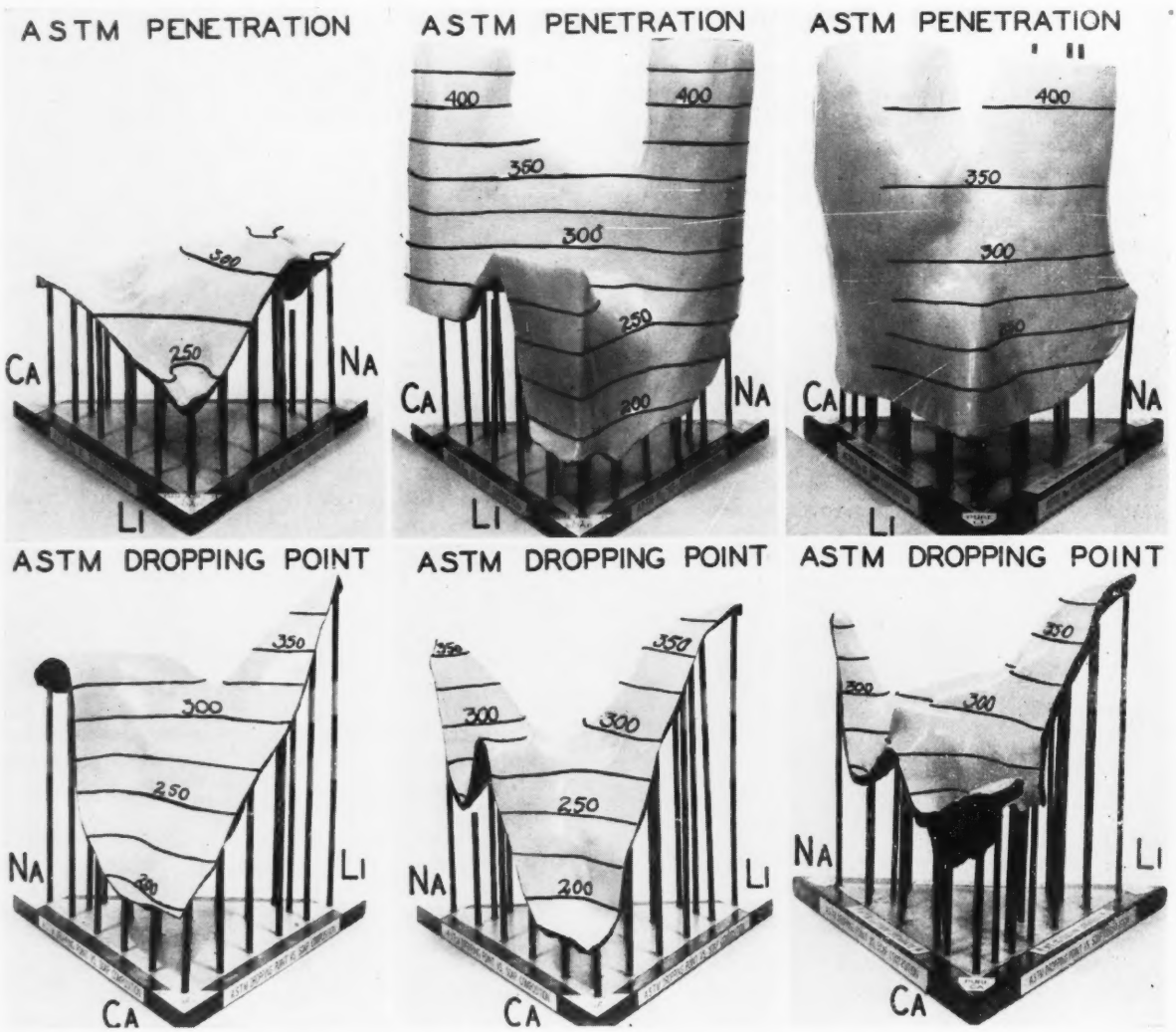


Fig. 3. (left) Consistency and dropping point models for cold mixed, commercial lithium, calcium, and sodium greases.

Fig. 4. (center). Consistency and dropping point models for mixed, commercial lithium, calcium, and sodium greases after stirring at 400 F.

Fig. 5. (right). Consistency and dropping point models for laboratory preparation of lithium, calcium, and sodium stearate greases.

3 and 4. Heating of the mixtures, similar to severe bearing operation, caused changes in the soap structure which resulted in completely fluid grease in some concentration areas, such as those near the 100% sodium soap and the 100% calcium soap points.

The effect on bearing performance of the fluid mixtures could not be determined because the samples were too fluid to remain in the test machine. A comparison was, therefore, made between each of the component greases and a mixture of medium consistency, and the results are illustrated in Figs. 6 and 7. Fig. 6 shows the performance of the sodium grease in the Antifriction Bearing Machine operated at 150 F. The other two greases showed substantially the same results. The performance of a cold mixed blend of three greases (60% calcium, 20% sodium, and 20% lithium soap) is shown in Fig. 7. The mixture of greases softened considerably and was badly aerated, as would be expected from the properties listed in Table II for this blend.

Further work on this ternary system was conducted using preformed lithium, calcium, and sodium stearates in the same paraffinic base oil. The samples were prepared by mixing these thickeners in the desired proportions in the oil, heating to 420 F. with stirring, and, finally, pan cooling. No water was added for hydration of the calcium soap; but the soaps were not dried, and some water was present. The samples were passed through a colloid mill to complete grease preparation. All blends contained 86% oil and 14% by weight of the mixed soaps.

Fig. 5 shows models of the consistency and dropping point surfaces for the laboratory greases. The data are tabulated in Table III. The marked similarity between these models and those for the heated samples shown in Fig. 4 is apparent. Electron micrographs of the grease mixtures prepared from preformed soaps showed poor fiber formation in the areas of the inferior greases. The blends containing mostly sodium stearate have large, platelike fibers which are not efficient in thickening the oil. The greases made with a majority of calcium stearate generally have small, spheroidal particles. There is no dimension of these particles sufficiently large to allow formation of a tangled mass of soap to hold the oil. On the other hand, the spheres are not small enough (like silica or aluminum stearate) to thicken the oil by some other mechanism. These differences in soap structure account for the variation in consistency of the grease mixtures. In contrast to the changes in soap structure shown in both the laboratory greases and the commercial grease mixtures after heating, the cold blends under the electron microscope show mixtures of well formed fibers, which exhibit less marked differences in physical properties. Thus, simply stirring the greases together at room temperature does not materially affect the crystal structure of the soap particles. Slight changes in the lattice built up from these fibers may account for the minor changes in consistency shown in Fig. 3.

Complex Commercial Grease Mixtures. A second three-grease system studied was more complicated in composition as each of the components contained two thickeners. These greases were encountered in the lubrication system of the steel mill and consisted of sodium-aluminum, calcium-lead, and lithium-calcium soap greases. The consistency and dropping point data for mixtures of these three commercial greases are given in Table IV. They show a departure from linear relationships which we have defined as incompatibility. When a mixture similar to that which existed in the steel mill system (equal parts of each of the three compon-

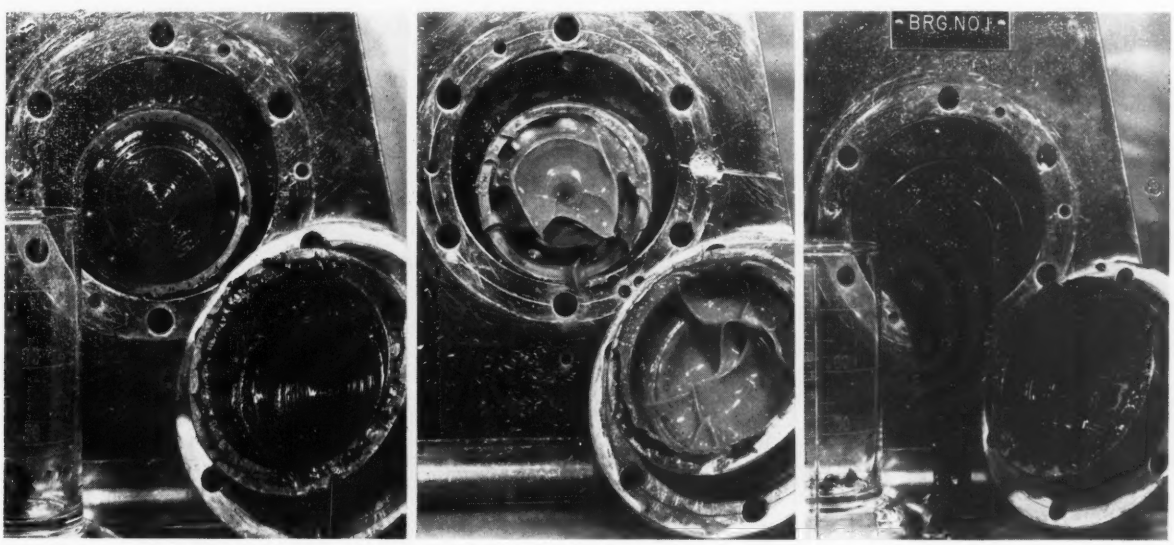


Fig. 6. (left). Sodium grease; Antifriction Bearing Machine operated at 150 F.

Fig. 7. (center). Lithium, calcium, sodium mixture; Antifriction Bearing Machine, operated at 150 F.

Fig. 8. (right). Complex mixture, three mixed soap greases; Antifriction Bearing Machine operated at 150 F.

Table III. Physical properties of mixed greases made from preformed stearates. Key: (1) Penetration, after 24 hours, of grease which had received no working other than that of mixing; (2) Penetration after 60 strokes in the ASTM worker; (3) Unworked grease so soft that P_{∞} was not measured; (4) Below 200 F.

Soap Composition, weight per cent			ASTM Penetration		ASTM Dropping Point, °F
Lithium	Sodium	Calcium	P_0(1)	P_{60}(2)	
100	-	-	219	243	383
84	8	8	204	244	370
72	14	14	189	256	360
60	30	10	162	216	301
60	10	30	178	229	333
50	50	-	181	195	305
50	25	25	178	274	312
50	-	50	206	215	322
43	43	14	185	227	294
43	14	43	221	344	298
33	33	34	191	306	285
30	60	10	258	272	292
30	10	60	338	400+	285
25	50	25	210	344	278
25	25	50	326	368	271
22	-	78	400+	(3)	(4)
14	72	14	318	400+	267
14	43	43	267	370	286
14	14	72	400+	(3)	(4)
11	-	89	332	309	260
10	60	30	286	400+	287
10	30	60	400+	(3)	(4)
8	84	8	380	400+	238
8	8	84	400+	(3)	(4)
-	100	-	296	317	350
-	50	50	350	363	271
-	18	82	400+	(3)	(4)
-	-	100	302	324	255

Table IV. Physical properties of mixed commercial greases. Key: (1) Penetration, after 24 hours, of grease which had received no working other than that of mixing; (2) Penetration after 60 strokes in the ASTM worker.

Soap Composition, weight per cent			ASTM Penetration		ASTM Dropping Point, °F
Calcium-Lead	Sodium-Aluminum	Lithium-Calcium	P_0(1)	P_{60}(2)	
100	-	-	326	353	201
80	20	-	340	353	192
80	10	10	332	349	194
80	-	20	332	349	208
60	40	-	336	364	186
60	20	20	332	349	206
60	-	40	328	342	261
40	60	-	340	368	271
40	40	20	317	355	227
40	20	40	311	343	246
40	-	60	321	332	286
33	33	34	313	351	251
20	80	-	336	372	324
20	60	20	324	358	252
20	40	40	305	333	243
20	20	60	296	345	274
20	-	80	315	315	327
10	80	10	324	363	330
10	10	80	292	330	315
-	100	-	280	368	397
-	80	20	322	355	319
-	60	40	300	336	300
-	40	60	292	336	276
-	20	80	284	326	309
-	-	100	275	297	357

ents) was tested in the Antifriction Bearing Machine at 150 F., the field experience was repeated as shown in Fig. 8. Individual component greases however, retained their structure in similar tests.

Conclusions. (1) Mixing of greases occurs in service and sometimes affects performance adversely. (2) Physical mixing of some greases in the laboratory produces changes in consistency and dropping point which are greatly accentuated by heating. (3) Laboratory performance tests demonstrate the instability associated with some grease mixtures. (4) Simple physical tests such as consistency and dropping point, often give indications of incompatibility of grease mixtures.

COMMENTARY by J. S. McGrogan (The Atlantic Refining Co.) The timing of this presentation is opportune because of the recent introduction of many new type soap and other oil thickeners. These new materials may lead to more troubles of this nature than we have experienced in the past. We feel the approach presented in the the paper is sound and when sufficiently expanded will provide useful tools for indicating compatibility.

We would like to review a point presented at the beginning of the paper. Quoting the authors, "In our extensive field experience with both automotive and industrial grease, we have observed a few cases of impaired service performance resulting from the mixing of two or more greases of different thickener type." We are concerned that this could be interpreted to mean that all the rest of the service incompatibility was experienced when two or more greases of the same thickener type is used. We believe the authors intended to say that only a few cases of service incompatibility have been experienced regardless of the thickener type used.

Along these lines it is of interest to note that ASTM has a subsection committee organized to study this problem. Since organization of this committee in 1953 not a single documented case of service incompatibility has been reported by representatives of the grease producer or consumer. We anticipate, therefore, that ASTM will welcome this paper and no doubt it will provide a basis for discussion and program guidance by the committee.

I would like to suggest that considerable thought be given to the definition of compatibility. The authors propose that greases are incompatible if the physical properties and service performance of their mixtures are poorer than would be expected from a linear relationship. We disagree to some extent with this definition and are of the opinion that only greases for similar service should be compared and, further, these greases would be incompatible only if the mixture is poorer than the poorest grease present. We see no reason to penalize a grease because it fails to raise the performance quality commensurate with its content in the mixture.

The authors reported studies of mixtures ranging from a minimum of 20% total contaminate up to 80% of this material. Some laboratory work we did with an experimental grease indicates a very critical range exists at lower concentration levels in the order of 5-10%. In this we are suggesting only an extension of the authors' work.

We believe the authors in presenting this information have paved the way for others, and that their studies, coupled with others in the grease industry, when completed will insure a more successful application of modern lubricating greases in the future.

COMMENTARY by R. F. Repenning (Shell Oil Co.). Historically speaking, our company introduced lithium 12-hydroxy stearate grease as a multipurpose automotive lubricant seven years ago and shortly thereafter an industrial grade of the same type product. However, in both cases marketing of the products was delayed until we had the results of extended comprehensive field trials which had been instituted to determine the feasibility of the multipurpose approach. At the time the trials were initiated we recognized, on the basis of laboratory data, that mixing the multipurpose product with other greases might result in degrading its performance characteristics. Both company and consumer equipment, by mutual agreement, was utilized in the test program. In some cases bearings were cleaned and repacked, but in most the multipurpose grease was added to whatever product was in the bearings. No evidence of incompatibility from a performance standpoint was noted throughout the test program. However, shortly after we introduced the multipurpose automotive type product to the market, a number of wheel bearing leakage complaints were reported. Careful investigation revealed that all bearings had been removed and thoroughly cleaned before relubrication, but also all had been

overpacked to insure adequate lubrication. As a result of the overpacking the churning action of the bearing forced the excess past the seals into the brakedrums. An intensive lubrication personnel instruction program showing the correct method of packing wheel bearings eliminated the problem.

In 1954 we decided to verify previous apparent lack of compatibility problems in terms of field performance. Questionnaires were submitted to a number of large industrial organizations who had used our multipurpose grease across the board for several years. Answers were obtained from: (a) a major steel producer, (b) a major nonferrous metal producer, (c) a major diesel engine builder, and (d) an automobile manufacturer. It was felt that the variety of applications encountered in the combined operations of these industries would encompass practically every type of critical equipment. The questions propounded in the questionnaire and answers received are as follows:

1. What types of greases were superseded by the lithium base grease? (All) Soap types.

2. How many greases altogether were superseded? Ranging from a minimum of three with one company to several dozen maximum with another company.

3. Did you expect any difficulty in substituting lithium base grease for the others? (a) None. (b) Minor effects. (c) Compatibility. (d) Appeared too light.

4. What steps did you take in preparing bearings, lubrication systems, etc., for the new grease? (a) Wiped out the system reservoirs and removed bearing drain plugs until new grease showed. Thirty days required before grease showed. (b) In most cases added with no preparation. On accessible electric motors and critical bearings they were cleaned and repacked. (c) Added as and when needed with no preparation. (d) In most cases pumped to bearings with drain plugs out. Some electric motors were cleaned and bearings repacked.

5. Did you notice any signs of "incompatibility," i.e. any abnormal conditions occasioned by mixing the lithium base grease with any other? (All) No.

In general, results at our own refineries paralleled the experiences indicated by the previous answers. For the same economic reasons, namely that high production equipment seldom can be shut down for bearing cleaning, our refineries added the multipurpose grease in most instances to whatever type product was in the bearing at the time.

We would revise the authors' conclusion, "Mixing of greases occurs in service and sometimes affects performance adversely," by suggesting that "Profuse mixing" is rather common practice. We would further state, however, that unless either one or both of the greases in a given mixture are marginal, and so inadequate for the specific application, our experience indicates there is little likelihood of problems resulting from so-called "incompatibility." Another point which is vitally important, and it has not been touched upon, is the effect on performance characteristics of various fats or fatty acids used in grease manufacture may have. The base metals are only one of the factors involved in the problem.

In conclusion, we would like to say that some of the laboratory techniques outlined in the paper may serve as a good guide to prevent promiscuous and thoughtless degrading of high quality multipurpose greases with low quality cheap greases. We have been able to find no evidence that a service compatibility problem per se exists when the lithium 12-hydroxy stearate multipurpose grease is mixed with any other grease in service unless either one or both products are inadequate for the application.

AUTHORS' CLOSURE. Mr. McGrogan is correct on two points. We do not wish to imply that incompatibility is usually found when two greases of the same thickener type are mixed. It is also true that other definitions of incompatibility are possible and perhaps ours is too strict in a service sense. Comparison of greases for similar service tends to avoid the cases which arise from accidental misuse. In a study to understand the reasons for incompatibility there is no need to limit the definition in this fashion, but it might be useful for service applications.

Mr. Repenning's case for lithium 12-hydroxy stearate grease is interesting in its service aspects, for certainly a variety of operations are represented. The tolerance of lithium 12-hydroxy stearate grease for greases of other soap bases may be extremely high; however, there also may be some cases in which the use of the lithium grease in bearings functioning satisfactorily on another grease would result in lubrication failure, or at least a degradation of properties. In this case, regardless of the suitability of the lower quality grease, in the eyes of the consumer it was performing satisfactorily until the lithium grease was applied, and the resulting mixture is termed "incompatible." The work described in the paper offers a method by which this difficulty may be foreseen and the possibility described to the consumer in advance.

New Products

Spray Valve Panels. Designed to spray-lubricate bull gears, girth gears such as on grinding mills and kilns, and other spur or herringbone gear trains, newly-developed Spray Valve Panels are fastened to gear housings or frame work and spray the lubricant directly to the pressure side of the gear teeth. Measuring approximately two feet by three feet, the panels feature stainless steel spray valves having built-in nozzles; central pumping units deliver gear lubricant at regular intervals through a circuit of Dualine measuring valves. The measuring valves distribute the lubricant under pressure to the spray valves where it is mixed with air to form a penetrating spray. (Bulletin 26-R, The Farval Corp., LE-11/6, 3267 E. 80th St., Cleveland 4, Ohio.)

Laboratory Stirrer. Powered by air, new Arrow Type A stirrers are ideal for stirring all types of solvents, lacquers, paints, oils, synthetics, and fine and heavy chemicals where danger of explosion may exist. A complete unit, ready for mounting on laboratory stand, speeds range from 400 to 10,000 rpm merely by turning the air supply line valve; only 25 to 100 lbs of air supply is necessary. Units take up their own wear, eliminating service cost; cannot burn out from overload. Shaft and propeller are made of stainless steel. (Arrow Engineering Co., LE-11/6, 200 Central Ave., Hillside, N. J.)

Unitary Mechanical Seals. Designed for use on process pumps, newly-developed Unitary Seals feature: one-piece assembly (the entire unit, including sleeve and gland, is self-contained), pre-set at factory (no on-the-job measurements or adjustments are necessary), Collett-type drive (no set screws to loosen, corrode, or damage shaft or shaft sleeve), external lock and drive (readily accessible), circulating connections in glands, and long life. (Bulletin AD-151, The Garlock Packing Co., LE-11/6, Palmyra, N. Y.)

Lubrikit. Something really new for replacement and plant mainte-

(Continued on p. 432)

Personals

J. L. Finkelmann, (above), The Warren Refining & Chemical Co., Cleveland, Ohio, has been elected to serve on the ASLE Board of Directors, replacing A. E. Roach, deceased.

R. K. Gould, The Texas Co., New York, N. Y., has been appointed Editor of **Lubrication Engineering** and Chairman of the ASLE Editorial Committee, replacing **S. K. Talley** who has completed a year's special assignment for Shell Oil Co. in New York City and has returned to new responsibilities with Shell Development Co., Emeryville, Calif.

Dravo Corp., Machinery Div., Pittsburgh, Pa., has announced the appointment of **K. D. Reed,** formerly affiliated with The De-Laval Separator Co., as Manager of its newly-created Lubrication Section.

R. T. Sheen, Milton Roy Co., has been elected President of the Instrument Society of America for the ensuing year, with **R. N. Pond,** Taylor Instruments Co., and **J. W. Percy,** U. S. Steel Corp., as Vice-Presidents in charge of the Technical and Recommended Practices Divisions, respectively; with **Dr. W. G. Brombacher,** Special Consultant for the National Bureau of Standards, as Secretary.

The American Society of Mechanical Engineers approved the application of "Lubrication Activity" for Division status, effective Nov. 13, with **Dr. D. F. Wilcock,** General Electric Co., as Chairman.

J. R. Hodges, Southwest Grease & Oil Co., Wichita, Kan., has been appointed Sales Representative for the company's southeastern territory.

The Texas Co. has expanded its specialized services to industry by opening a Technical Service headquarters in Pittsburgh, Pa. (address: Gateway Center, Bldg. No. 1, Rm. 5 South), under the direction of **J. C. VanGundy,** Technical Representative.

E. W. Baumgardner has been appointed Sales Manager of Trabon Engineering Corp., Cleveland, Ohio.

Obituaries: **I. C. Smith** (ASLE Cincinnati Section), Allis-Chalmers Mfg. Co., Norwood, Ohio, June 28; **E. F. Graves** (ASLE Director, 1944-46), Dow Chemical Co., London, England, Aug. 23; **A. P. Stensrud** (ASLE Twin Cities Section), The Texas Co., Golden Valley, Minn., Sept. 11.

R. K. Gould (above), newly-appointed Editor of **Lubrication Engineering,** is a graduate of Duke University (A.B., 1938; M.A., 1939; and PhD, 1941), and has been employed with The Texas Company since 1941. Acquiring a broad and varied background in the fields of petroleum processing and industrial lubrication, he is currently engaged in technical service activities on industrial lubricants, and serves as Editor of The Texas Company's well-known monthly magazine, "Lubrication."

Patent Abstracts

(Compiled by Ann Burchick, Aluminum Co. of America.)

Means for Lubricating Sheet Metal During Rolling, Patent No. 2,707,098 (G. E. Turpin, assignor to The Steel Co. of Wales Ltd.) An apparatus for producing a spray of atomised liquid such as heated palm oil, comprising an inner tube, an oil injection nozzle disposed within one end of said inner tube, spray delivery means at the other end of said inner tube, an intermediate tube surrounding the inner tube but spaced therefrom to form an intermediate annular heating jacket, means for passing heating fluid along said heating jacket, an outer tube surrounding the intermediate tube but spaced therefrom to form an outer annular chamber, which is of small radial thickness and is shorter in axial length than the heating jacket, said outer annular chamber being carried wholly upon the outside of the intermediate tube, means for feeding compressed air into the outer annular chamber at that end thereof adjacent the delivery end of the inner tube, transfer conduit means forming a connection for compressed air extending from the outer annular chamber directly into the inner tube at the inlet end thereof, and fins anchored to the outside of the intermediate tube and extending outwards within the outer annular chamber to increase the transmission of heat to the compressed air before it reaches the transfer conduit means.

Stabilized Mineral Oil Lubricant Compositions, Patent No. 2,707,172 (T. L. Cantrell & H. G. Smith, assignors to Gulf Oil Corp.) A lubricant composition comprising a major amount of a mineral lubricating oil and minor amounts, in a total of from 0.01 to 1 per cent by weight of said oil of: (1) 2,6-ditertiarybutyl-4-methyl phenol; and (2) a non-resinous condensation product of 1 mol of paratetramethylbutyl phenol, 4 mols of N-dimethylaniline and 4 mols of formaldehyde, the condensation of said product having been carried out in the presence of from 5 to 10 per cent by weight on the reactans of an activated clay catalyst at a temperature of from 150 to 300 F. to condense together the three reactants; the amounts of (1) and (2) with respect to each other being in a weight ratio ranging from 1:4 to 4:1.

Stabilized Mineral Oil Lubricant Compositions, Patent No. 2,707,173 (T. L. Cantrell & H. G. Smith, assignors to Gulf Oil Corp.) A lubricant composition comprising a major amount of a mineral lubricating oil and minor amounts, in a total of from 0.01 to 1 per cent by weight of said oil, of: (1) 2,6-ditertiarybutyl-4-methyl phenol; and (2) a non-resinous condensation product of 1 mol of N-dimethylaniline and 2 mols of formaldehyde, the condensation of said product having been carried out in the presence of an activated clay catalyst at a temperature not in excess of 350 F. to condense together the two reactants; the amounts of (1) and (2) with respect to each other being in a weight ratio ranging from 1:4 to 4:1.

Stabilized Mineral Oil Lubricant Compositions, Patent No. 2,707,174 (T. L. Cantrell & H. G. Smith, assignors to Gulf Oil Corp.) A lubricant composi-

(Continued on p. 423)

Foote Lithium Does It!

ONE

Lithium Base,

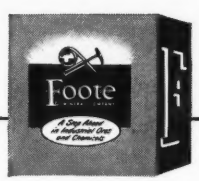
Multi-Purpose Grease

Assures Correct Lubrication

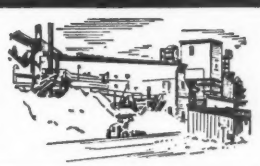
It's a fact! You are assured of correct lubrication for practically all jobs when you use ONE lithium base grease . . . a multi-purpose grease. No need to use a whole series of single purpose greases, because this ONE lithium grease not only resists water but lubricates efficiently at temperatures ranging from —50°F. to over 350°F.

As a result of this ONE grease, inventory is greatly reduced and simplified lubrication procedures result in more efficient, economical operations.

It will pay you to contact your grease supplier for information about lithium base, multi-purpose lubricating grease.



LITHIUM HYDROXIDE FOR INDUSTRY



Kings Mountain, N.C. . . . where Foote is mining large deposits of spodumene.

Sunbright, Va. . . . the world's largest lithium chemical plant.

FOOTE MINERAL COMPANY
447 Eighteen West Chelten Building, Philadelphia 44, Pa.
RESEARCH LABORATORIES: Berwyn, Pa. • PLANTS: Exton, Pa.; Kings Mountain, N.C.; Sunbright, Va.

(Men of Lubrication, from p. 375)
an extraordinary talent for finding and elucidating the most obscure and at the same time most important parts of a subject, and this has given his work an unusually lasting quality. No one could have foreseen the great technical value of Rayleigh's work in acoustics at the time he wrote it, but with the development of telephony and radio it took on a new importance and his work was eagerly studied by those in the new field of applied acoustics.

In addition to his mastery of theoretical physics, for which he is perhaps best known to modern technical workers, Rayleigh was also a great experimental physicist. He had the ability to get great accuracy from apparatus of the most simple form, and this is nowhere better illustrated than in his classical work on the determination of the ohm. His discovery of the rare gas, Argon, in the atmosphere is regarded as the most striking example of his experimental skill, and the complete story is one of almost incredible attention to minute detail in an experiment which extended over nearly ten years. The object of the experiment was to determine the densities of the permanent gases: oxygen, hydrogen, and nitrogen, as there were considerable discrepancies in the various values that had been reported. The matter was of fundamental importance in the problem of atomic weights. In the case of nitrogen, the gas was obtained from the air; the other constituents being removed by various treatments. The density found by Rayleigh, for nitrogen obtained in this way, was in very close agreement with the most recent determination. However, Rayleigh with characteristic thoroughness tried another method of preparing the specimen which actually gave a mixture of atmospheric nitrogen and nitrogen from a chemical source. The new specimen was found to have a density about a tenth of one per cent less than those obtained from the air alone. (The actual weight discrepancy was 2.3 milligrams in a total weight of about one or two pounds). This small clue led to the discovery of Argon and ultimately, by others, to the discovery of the other rare gases of the atmosphere. For his work on the density determinations and for the discovery of Argon, Rayleigh received the Nobel Prize for Physics in 1904.

During the course of an entire lifetime devoted to science, Lord Rayleigh wrote nearly 450 papers which cover the entire field of classical physics. His importance in the engineering sciences can be judged from the large number of references to his work in the various books by Professor Timoshenko. But electrical engineering is equally indebted to him, and, indeed, any worker in the so-called exact sciences can usually find that Rayleigh had something of importance to say in his field. Rayleigh's papers are published in six large volumes of his "Collected Papers," and it is of interest to quote in this connection from Sir J. J. Thomson's memorial address in Westminster Abbey on the occasion of the unveiling of a memorial tablet: "Among the 446 papers which fill these volumes, there is not one that is trivial, there is not one which does not advance the subject with which it deals, there is not one which does not clear away difficulties, and among that great number there are scarcely any which time has shown to require correction. It is this, I think, which explains that while the collected papers of scientific men often form a kind of memorial tablet in our libraries, respected, but not disturbed, those of Lord Rayleigh are among the most frequently consulted books in the physicist's library."

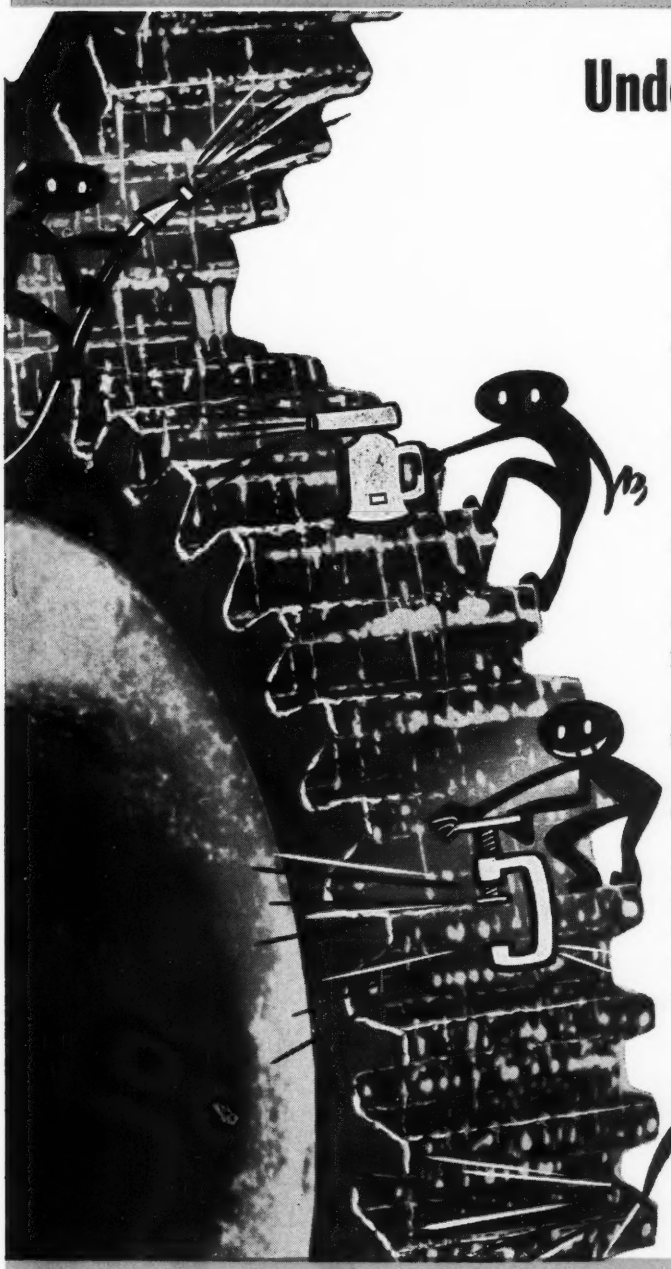
For five years following the death of Clerk Maxwell, Rayleigh held the chair of experimental physics at Cambridge University, but following this tenure his work was almost entirely done in a laboratory in his home. As he grew older his reputation became tremendous and his services were sought on all sides. He gave generously of his time, but his output of scientific work seems to have been unaffected. In 1908 he was installed as Chancellor of Cambridge University. During the first world war his advice was sought in many ways, particularly on the technical problems of aircraft. Rayleigh also took a leading part in the establishment of the National Physical Laboratory. From 1905 to 1908 he was president of the Royal Society. In the course of his long career he was honored by universities, learned societies, and governments all over the world.

Rayleigh seems to have been a kindly man with a quiet sense of humor. In appearance he has been described as more like a banker than what is popularly thought of as a scientist. He was a man of considerable independent means and this allowed him to follow his scientific bent with a degree of freedom not possible for many workers. But his son relates that his instincts were most economical in matters of money though, as he says and there is ample proof, this had nothing of the element of meanness about it. It may come as a relief to many engineers to learn that this great man, who was in no way an eccentric, did not have very much interest in the so-called cultural subjects. He read little that was not scientific, except the newspapers; and, though he enjoyed music, he made no effort to seek entertainment from it except in his own home to a small extent. He was keenly interested in the politics of his time, and as a member of the House of Lords spoke occasionally. His views in politics were conservative. He was, rather surprisingly, all his life interested in the phenomena called spiritualistic and was a member, and late in life president, of the Society for Psychical Research. He was apparently never "convinced," but his presidential address to the society relates some results of his experiments in this field and is interesting as the account of a first-rank man of science in this precarious kind of enquiry.

Lord Rayleigh died in 1919. He is buried in a church yard near his home, Terling Place. In 1921 a memorial tablet was placed to his memory in Westminster Abbey bearing the inscription:

"John William Strutt, O.M., P.C., 3rd Baron Rayleigh, Chancellor of the University of Cambridge 1908-1919, President of the Royal Society

Houghton TENAC Adheres to gears longer



Under TOUGH Conditions!

Stand-Out Advantages of this Free-Flowing, Fast-Setting Lubricant Make it Ideal For Your Heaviest Gear and Cable Applications...

- **EASY APPLICATION**—Use brush, swab, spray or drip feed—no preheating necessary.
- **FAST SETTING ACTION**—Tenac contains a special solvent which evaporates after application, leaving a tough, elastic film.
- **HIGH FILM STRENGTH**—Tenac's tough, flexible film will not separate or become brittle.
- **LONG-LASTING PROTECTION**—Tenac continues to protect metal surfaces even after extended periods of heavy duty service.
- **HIGH FLASH POINT**—Flash point for Tenac is far higher than that of similar lubricants.
- **PRE-TESTED**—Passes "Four Gram Retention Test"

For more detailed information on how Tenac, available in 3 grades — can reduce your lubricant costs, call your Houghton Man or write to E. F. Houghton & Co., 303 W. Lehigh Avenue, Philadelphia 33, Pa.

• FOR ALL OPEN GEARS AND CABLES— Tenac Lubricants (Light, Medium and Heavy) are recommended for open gears and cables of presses, shovels, hoists, elevators, shears, overhead cranes, open drives, etc.

TENAC—A PRODUCT OF

E F HOUGHTON & CO.

PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO

Ready to give you on-the-job service...

1905-1908, An Unerring Leader in the Advancement of Natural Knowledge."

ACKNOWLEDGEMENTS. The principal sources consulted in the preparation of this article were: "Life of Lord Rayleigh," by his son the Fourth Baron Rayleigh;"Historical Introduction to Lord Rayleigh's Theory of Sound," by Prof. R. B. Lindsay (Dover Publications), and Rayleigh's obituary notice by Sir Arthur Schuster (Proc. Roy. Soc. A, Vol. 98).

(This is the sixth in a series of articles by F. R. Archibald, Analyst, of Arthur D. Little, Inc.)

(Lube Lines, from p. 371)

ing conditions of the machine give less dependable protection to gears and bearings, and oftentimes a higher rate of wear, to result in the premature renewal of parts. Ineffective means of application of oil or grease can promote higher operating temperatures due to friction or even inability of the lubricant to reach the operating parts.

The process of lubrication involves more than just keeping a film of oil or grease on these parts. As applied to the plain or sleeve-type bearing such as is used on steam turbines, the process involves the fluid lubricant being drawn into the clearance space between the shaft and bearing by the pumping action of the turning shaft. The viscosity or relative fluidity of the film is directly related to its load-carrying ability. (A. F. Brewer, Consultant.)

Report from ASLE Administrative-Secretary. ASLE is continuing its rapid growth pattern, increasing in size, activities, and responsibilities.

Your Society has come a long way in the last few years, with a membership today of over 2600, and we are looking forward to a tremendous increase in the next year due to the fine program now in process by your Membership & Admissions Committee. If every member would enroll a new member this year it would be extremely simple to double the size of ASLE. If you know someone in an industrial plant who is in charge of lubrication and is not now a member, send his name and address to the National Office, or turn it over to your local Section Membership Chairman, and all the information on Society activities and services will be sent to him.

Each year ASLE members have had more services offered to them. In 1955 your Society joined forces with the Engineering Societies Personnel Service, thus making available to all members a national personnel organization. In addition to this, two new reference files have been set up in the National Office for the use of members: the first, a Consulting Lubrication Engineer reference list established to handle inquiries from interested manufacturers who need the services of qualified lubrication

DAYS NEVER END FOR SINCLAIR RESEARCH...

Developing Lubricants for Industrial Efficiency

- TURBINES
- DIESEL ENGINES
- STEAM ENGINES
- PLANT MACHINERY
- CONSTRUCTION MACHINERY
- METAL WORKING
- AUTOMOTIVE EQUIPMENT

Sinclair Research Laboratories at Harvey, Illinois, are working constantly to develop new products and improve the quality of existing ones. At these famous laboratories were developed the Sinclair lubricants now solving difficult problems in all branches of industry. A letter to Sinclair today may help you solve *your* lubrication problems, too.

SINCLAIR REFINING COMPANY

600 FIFTH AVENUE, NEW YORK 20, N. Y.

engineers. The other reference file is one of Industrial Distributor members of ASLE, for use by manufacturers and suppliers of products in the lubrication engineering field who wish new outlets.

The Society is now working in conjunction with the McGraw-Hill Book Company in the preparation of a Lubrication Engineering Handbook which will be off the press in about three years. This will be the culmination of many years of work and will provide the entire field with a standard reference volume compiled by experts on every subject.

In their efforts to provide more service to ASLE members, the Board of Directors have proposed that in the near future the Society Journal, **Lubrication Engineering,** become a monthly publication.

In order that every ASLE member may have an equal opportunity to take part in National Society activities, your 1956 membership invoice will be again utilized for a membership survey. This year's survey will cover the preference of each member as to the National Committees of the Society he would like to work with in the coming years.

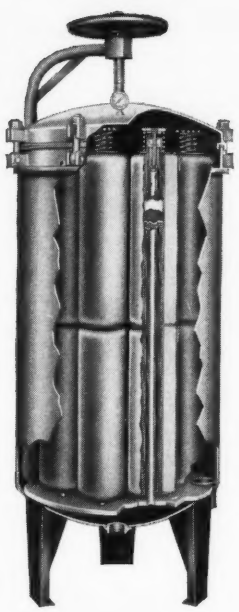
As all of these new services, activities, responsibilities, and improvements increase the budgetary requirements of the Society, the ASLE Board of Directors at their meeting during the 2nd Annual ASLE-ASME Lubrication Conference in Indianapolis, October 11, 1955, approved an advance in membership dues from $12.50 to $15.00 per annum, effective January 1, 1956. This will insure the continued growth of the Society and the success of its expansion program which will cover the increasing requirements desired by members, local Sections, and National Committees.

Lubrication Engineering is growing in importance in the design and operation of modern machines and industrial plants, and it is with these important developments in mind that the Board of Directors and the Officers of the Society have worked out a long-range program.

The Officers, the Board of Directors, and the National Office look forward to serving you in 1956, and working closely with all members in every phase of ASLE development. (Wm. P. Youngclaus, Jr.)

(Patent Abstracts, from p. 418)
tion comprising a major amount of a mineral lubricating oil and minor amounts in a total of from 0.01 to 1 per cent by weight of said oil, of: (1) 2,6-ditertiarybutyl-4-methyl phenol; and (2) a non-resinous condensation product of 1 mol of a xylidine, 1 mol of N-dimethylaniline and 1 mol of formaldehyde, the condensation of said product having been carried out in the presence of an activated clay catalyst at a temperature not in excess of 350 F. to condense together the three reactants; the amounts of (1) and (2) with respect to each other being in a weight ratio ranging from 1:4 to 4:1.

Stabilized Mineral Oil Lubricant Compositions, Patent No. 2,707,175 (T. L. Cantrell & H. G. Smith, assignors to



108 Standard Models

Honan-Crane Multi-Cartridge Filter

Why 108 models of the same basic filter? *Because each oil filter application creates individual problems.*

Scores of variable factors are involved: type of oil, additives, oil viscosity and temperature, flow rate, capacity, space available, nature and degree of contamination, type of heating required, and many more. *All* of these factors must be considered in selecting the proper filtration unit.

Honan-Crane Multi-Cartridge Filters are available in 108 models, 10 sizes, and with six different types of interchangeable cartridges, each designed to do a special filtering job.

Thus, no matter how unusual or difficult the application, you get a filter exactly suited to your requirements . . . and readily adaptable to *changing* requirements.

The same wide choice of models is also offered in Honan-Crane Bulk Refill and Full Flow type Oil Filters. Custom filtration performance is *standard* with Honan-Crane.

Write for three 8-page Equipment Bulletins:
No. 101—Full Flow Filters
No. 201—Multi-Cartridge Filters
No. 301—Bulk Refill Filters

of Indiana HH
HOUDAILLE-HERSHEY OF INDIANA, INC.
FILTRATION DIVISION

A SUBSIDIARY OF
COMMERCIAL FILTERS CORP.
818 Wabash Ave., Lebanon, Indiana

Gulf Oil Corp.) A lubricant composition comprising a major amount of a mineral lubricating oil, and minor amounts, in a total of from 0.01 to 1 per cent by weight of said oil, of: (1) 2,6-ditertiarybutyl-4-methyl phenol; and (2) a non-resinous condensation product of 2 mols of N-diethyl-m-toluidine, 1 mol of N-dimethylaniline and 2 mols of formaldehyde, the condensation of said product having been carried out in the presence of an activated clay catalyst at a temperature not exceeding 350 F. to condense together the three reactants; the amounts of (1) and (2) with respect to each other being in a weight ratio ranging from 1:4 to 4:1.

Tricresyl Phosphate-Chlorinated Biphenyl Functional Fluid Improved by Alkylated Polystyrene, Patent No. 2,707,176 (H. R. Gamrath & R. E. Hatton, assignors to Monsanto Chemical Co.) A functional fluid comprising in parts by weight, 40 to 55 parts of tricresyl phosphate, 45 to 60 parts of chlorinate biphenyl containing a total of 40 to 60% by weight of combined chlorine and 0.4 to 2 parts of alkylated polystyrene made by alkylating polystyrene having a molecular weight of between 10,000 and 150,000 with about 0.2 to 0.8 part by weight of olefins containing 6 to 15 carbon atoms, said functional fluid having a viscosity of 100 F. within the range of 150 to 1200 S.S.U. and a viscosity index within the range of 0 to +150.

Removal of Thiophenes from Aromatic Hydrocarbons, Patent No. 2,707,699 (C. A. Johnson & S. C. Schuman, assignors to Hydrocarbon Research, Inc.) A process of desulfurizing an aromatic hydrocarbon oil, which comprises bringing hydrogen and an aromatic hydrocarbon oil containing cyclic sulfur compounds into contact with an alumina of high surface area and free of added catalysts and promoters in a reaction zone maintained at a temperature in the range of 900 to 1300 F., the contact of said hydrogen and said aromatic oil resulting in a net consumption of hydrogen, passing said aromatic oil through the reaction zone at a space velocity in the range of about 0.2 to 3 liquid volumes per hour per volume of said alumina, maintaining the partial pressure of hydrogen in said reaction zone in the range of 100 to 750 psi, and recovering from the resulting reaction effluent said aromatic oil with a substantially reduced sulfur content.

Light Stable Petrolatum, Patent No. 2,707,705 (G. J. Rozman, assignor to Ashland Oil & Refining Co.) A light-colored petrolatum containing between approximately 0.1 and 0.001% furfuralazine by weight.

Preparation of Oil-Soluble Organic Sulfonates, Patent No. 2,708,182 (E. J. Jahn, assignor to Shell Development Co.) In a process for the conversion of a mineral oil solution of sodium petroleum sulfonates to a mineral oil solution of the corresponding calcium petroleum sulfonates wherein said mineral oil solution of sodium petroleum sulfonates is reacted with calcium chloride and calcium hydroxide at a temperature of about 180 F. to about 200 F., in the presence of about 80% by weight, of water based on the sodium petroleum sulfonates, the improvement comprising effecting said conversion in the presence of about 10%, by weight, based on the sodium petroleum sulfonates. of a partially water-soluble polyoxyethylene derivative of sorbitan trioleate.

Method for the Preparation of Mixed Base Greases, Patent No. 2,708,659 (E. O. Forster, assignor to Esso Research & Engineering Co.) A process for the preparation of lubricating grease compositions having outstanding water resistance and high temperature properties which comprises the steps of dispersing in the presence of water from about 2.5% to about 15.0% by weight, based on the weight of the final grease composition, of a calcium soap of a high molecular weight fatty acid in a lubricating oil, subsequently dispersing a second soap selected from the group consisting of barium, strontium and magnesium soaps of high molecular weight substantially saturated fatty acids in said mixture in amounts such that the mol ratio of said calcium soap to said second soap is from 8:1 to 1:8, and heating the resulting mixture up to a temperature of about 250 F. to dehydrate said resulting mixture, subsequently heating to a temperature between about 350 to 420 F. and cooling the resulting composition.

Soluble Oil Rust Inhibitors, Patent No. 2,708,660 (S. E. Jolly, assignor to Sun Oil Co.) A mineral soluble oil capable of forming stable emulsions in water and containing an emulsifying agent and a rust-inhibiting quantity of an additive material.

Oxidation-Inhibited Mineral Oil Compositions, Patent No. 2,709,156 (J. W. Bishop & J. J. McBride, Jr., assignors to Tide Water Associated Oil Co.) A composition comprising a mineral oil in major amount based on the weight of the composition and a small amount, sufficient to inhibit said composition against oxidation, of an oil-soluble oxidation-inhibiting addition product.

Hydrocarbon Oil Compositions, Patent No. 2,710,282 (J. Linsk & C. S. Scanley, assignors to Standard Oil Co.) A hydrocarbon oil composition comprising a major proportion of a hydrocarbon oil and a small proportion, sufficient to improve the pourpoint properties of said oil, of an ester of an aliphatic alcohol with a tripolymer, having a molecular weight of from about 1000 to about 40,000, of an unsaturated hydrocarbon selected from the group consisting of an acyclic unsaturated hydrocarbon, an alicyclic unsaturated hy-

BENTONE* 34

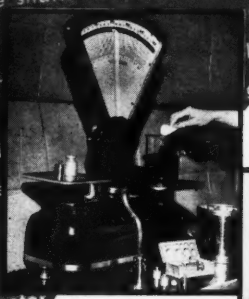
Grease Manufacturers and Distributors

THE ACME REFINING CO., Cleveland, Ohio
ADAM COOKS SONS, INC., Linden, N. J.
ALEMITE DIV., STEWART-WARNER CORP., Chicago, Ill.
ALLUBE CORP., Glendale, Calif.
THE AMERICAN LUBRICANTS CO., Dayton, Ohio
ARKANSAS FUEL OIL CORP., Shreveport, La.
BATTENFELD GREASE & OIL CORP., Kansas City, Mo.
BATTENFELD GREASE & OIL CORP. OF CALIFORNIA, Compton, Calif.
BATTENFELD GREASE & OIL CORP. OF NEW YORK, North Tonawanda, N. Y.
BEL-RAY CO., INC., Madison, N. J.
THE BROOKS OIL CO., Pittsburgh, Pa.
CASCADE PETROLEUM CO., Denver, Colo.
CATO OIL AND GREASE CO., Okla. City, Okla.
CONSUMERS COOPERATIVE ASSOCIATION, Kansas City, Mo.
CRAWFORD EMULSIONS, Pittsburgh, Pa.
DENS-OIL LUBRICANT CO., Kansas City, Mo.
JAMES W. DOYLE CORP., Detroit, Mich.
FISKE BROTHERS REFINING CO., Newark, N. J.
FISKE BROTHERS REFINING CO., Toledo, Ohio
THE FRANKLIN OIL AND GAS CO., Bedford, O.
GEORGIA-CAROLINA OIL CO., Macon, Georgia
GLOBE GREASE & MFG. CO., Los Angeles, Calif.
GOPLERUD LUBRICANTS CO., Mason City, Iowa
GREDAG, INC., Niagara Falls, N. Y.
HI-WAY REFINERIES, LTD., Regina, Sask., Canada
THE HODSON CORP., Chicago, Ill.
THE HODSON CORP. (QUEBEC), INC., Three Rivers, Quebec, Canada
E. F. HOUGHTON & CO., Philadelphia, Pa.
ILLICO INDEPENDENT OIL CO., Lincoln, Ill.
INTER-STATE OIL CO., Kansas City, Kansas
KEYSTONE LUBRICATING CO., Philadelphia, Pa.
LUBRICATION CO. OF AMERICA, Los Angeles, Calif.
MacMILLAN OIL CO. OF ALLENTOWN, Allentown, Pa.
MAGIE BROTHERS, INC., Chicago, Ill.
MAGNUS CHEMICAL CO., Garwood, N. J.
MANITOBA CO-OPERATIVE WHOLESALE LTD., Winnipeg, Man., Canada
METALCOTE OIL CO., St. Paul, Minn.
MID-STATES LUBRICANTS, Kansas City, Mo.
MIDWEST OIL CO., Minneapolis, Minn.
THE OHIO GREASE COMPANY, Loudonville, O.
OIL-KRAFT, INC., Cincinnati, O.
OIL DISTRIBUTORS OF PHILADELPHIA, Philadelphia, Pa.
ONYX INTERNATIONAL, Jersey City, N. J.
PANTHER OIL & GREASE MFG. CO., Fort Worth, Texas
PANTHER OIL & GREASE MFG. CO. OF CANADA, Toronto, Ontario, Canada
PENN-CREST OIL & GREASE CORP., Long Island City, N. Y.
PENN PRODUCTS CO., DuBois, Pa.
PHOENIX OIL COMPANY, Augusta, Ga.
A. B. PLATING SUPPLY CO., Milwaukee, Wisc.
PRAIRIE STATES OIL & GREASE CO., Danville, Ill.
PRECISION BEARING & TRANSMISSION CO., Omaha, Nebr.
RILEY BROS., INC., Burlington, Iowa
SASKATCHEWAN FEDERATED COOP. LTD., Regina, Sask., Canada
ADOLF SCHMIDS ERBEN S. A., Berne, Switzerland
SERVICE LUBRICANTS, INC., Chicago, Ill.
L. SONNEBORN SONS, INC., New York, N. Y.
SOUTHWEST GREASE & OIL CO., INC., Wichita, Kan.
SOUTHWESTERN PETROLEUM CO., Fort Worth, Texas
SPECIALTY PRODUCTS CO., Jersey City, N. J.
SUNLAND REFINING CORP., Fresno, Calif.
SYRACUSE FIRE BRICK SUPPLY, Syracuse, N. Y.
THREE RIVERS REFINERY, Three Rivers, Tex.
TIDE WATER ASSOCIATED OIL CO., N. Y. C.
TIONA PETROLEUM CO., Philadelphia, Pa.
TOPSALL LUBRICANTS, INC., Kenmore, N. Y.
TOWER OIL CO., Chicago, Ill.
TRANSMISSION EQUIPMENT CO., Pittsburgh, Pa.
TRI-STATE PETROLEUM CO., Philadelphia, Pa.
UNITED COOPERATIVES, INC., Alliance, Ohio
UNIVERSAL AVIATION SUPPLY, Wichita, Kan.
C. C. WAKEFIELD & CO., LTD., Toronto, Ontario, Canada
THE WARREN REFINING AND CHEMICAL CO., Cleveland, Ohio
THE WAVERLY OIL WORKS CO., Pittsburgh, Pa.
WESTLAND OIL CO., Minot, N. D.

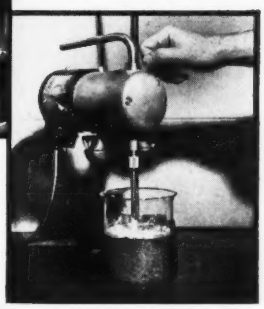
*T.M. Reg.

NATIONAL LEAD CO.
BAROID DIVISION
P. O. Box 1675, Houston 1, Texas

Bentone* 34 Grease Multi-Tested for a Thousand Uses!

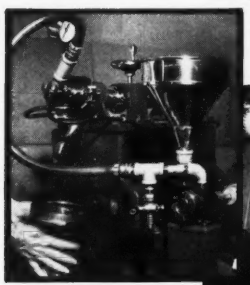


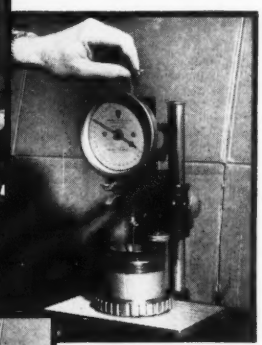
EXACT FORMULATION — various formulas are tested until one is produced that meets all of manufacturer's requirements.



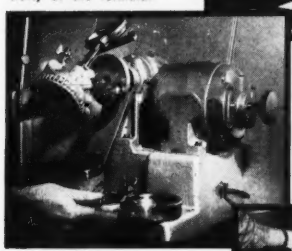
MIXING—mixing prepares formula for milling.

MILLING—milling or homogenizing produces a smooth, consistently uniform grease.

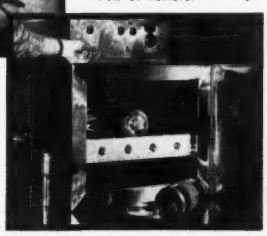




EXACT CONSISTENCY — penetrometer tests indicate consistency or hardness of grease sample and determine the plasticity of the formula.



EXCELLENT MECHANICAL STABILITY — roller tests measure mechanical stability of grease and produce a numerical evaluation — during penetration testing — of the change in consistency caused by kneading or working action of rollers.



HIGH SHEAR STABILITY—shear stability tests exert influence far in excess of any working pressures for which grease will be used.

EVERY DAY Baroid's extensive laboratories assist grease compounders to formulate greases with Bentone* 34 gelling agents. Compounders throughout the country have used Baroid laboratory service to obtain the best formula — using *their* oil and Bentone* 34 — to make a grease that's right for thousands of applications. For the farm . . . automotive industry . . . industrial machinery of every kind — grease made with Bentone* 34 serves a need not met by any other type of lubrication. Its unique composition has a tenacious quality that causes it to adhere to metal . . . has a matchless resistance against rain and washout . . . works well under both *extreme* high and low temperatures! It answers a multitude of lubrication problems because one Bentone grease is good for scores more applications than any known conventional lubricant.

Bentone grease is always uniform, always the same high quality. Write today for illustrated brochure about Bentone* 34 gelling agent.

BENTONE* 34

THE NON-SOAP GELLING AGENT

NATIONAL LEAD COMPANY ★ BAROID DIVISION

P. O. BOX 1675 ★ HOUSTON, TEXAS

★ ★ ★ USE ★ ★ ★

CRESOL

ADDITIVES

★ ★ ★ ★ ★ ★ ★ ★

in the preparation of:

Cutting Oils
Drawing Oils
Grinding Oils
Metal Working Oils
Engine & Heating Fuels
Rust Preventives

For
Exceptional Performance
at Low Cost
use

- CRESOL Z-1, for EP Gear Oils, Cutting Oils, Drawing and Stamping Oils
- CRESOL Z-2, for Cutting Oils, Grinding Oils
- CRESOL Z-3, for EP Lubricants, Drawing Compounds
- CRESOL Z-4, for Soluble Drawing Oils and Cutting Oils
- CRESOL Z-5, Oxidation Inhibitor for Lubricating Oils
- CRESOL Z-7, for Automatic Transmission Fluids
- CRESOL Z-51, for Rust Preventives (Oil and Solvent Type), Lubricity Agent for Lubricating Oils, Fatty Oil Replacement
- CRESOL 22-C, Engine and Heating Oil Additive to prevent carbon deposits

Samples, and suggested formulae for general or specific applications, available upon request.

★

BURNS LABORATORIES, INC.
514 WEST WYOMING STREET
INDIANAPOLIS, IND.

drocarbon and mixtures thereof, an unsaturated polybasic compound selected from the group consisting of maleic acid, fumaric acid, aconitic acid, itaconic acid, citraconic acid and anhydrides thereof, and an alkyl vinyl ether having 2 to about 18 carbon atoms in the alkyl group, said unsaturated hydrocarbon, said unsaturated polybasic compound, and said alkyl viny! ether being employed in the molar ratio of from about 1:10:9 to 9:10:1.

Oil Compositions, Patent No. 2,710,283 (Jack Linsk, assignor to Standard Oil Co.) A composition comprising a major proportion of a hydrocarbon oil and a small proportion, sufficient to improve the Viscosity Index and pourpoint properties of said hydrocarbon oil, of an ester of an aliphatic monohydroxy alcohol having at least 2 carbon atoms with a tripolymer, having a molecular weight of from about 5000 to about 200,000, of styrene, an unsaturated polybasic compound selected from the group consisting of maleic acid, fumaric acid, aconitic acid, itaconic acid, citraconic acid and the anhydrides thereof, and an alkyl vinyl ether having from about 2 to about 18 carbon atoms in the alkyl group, said styrene, unsaturated polybasic compound, and alkyl vinyl ether being employed in the molar ratio of from about 1:10:9 to 9:10:1.

Recovery of Guanidine Petroleum Sulfonates as Oil Detergents, Patent No. 2,710,303 (W. B. Whitney, assignor to Phillips Petroleum Co.) A process for the separation of mineral oil soluble guanidine petroleum sulfonates from incompletely mineral oil soluble guanidine petroleum sulfonates in mixture therewith, comprising admixing with said guanidine petroleum sulfonate mixture at least an equal volume of a normally liquid ketone, heating the resulting admixture to an elevated temperature so as to dissolve all of said guanidine petroleum sulfonates in said ketone and then cooling the said admixture until incompletely oil soluble guanidine petrolum sulfonates precipitate therefrom, and recovering oil soluble guanidine petroleum sulfonates from the resulting mother liquor as a product of the process.

Lubricating Compositions, Patent No. 2,710,837 (P. R. McCarthy, assignor to Gulf Research & Development Co.) A lubricant comprising a dispersion of a metallic soap of a fatty acid and a compound of a bentonite and an organic nitrogen base in a mineral lubricating oil, wherein said metallic soap is present in said lubricant in an amount corresponding to about 2 to about 10 per cent by weight of the lubricant and wherein said bentonite compound is dispersed in said oil in an amount sufficient to produce a lubricating base having the consistency of a grease.

Thixotropic Lubricating Grease Containing Polycarboxylic Acid Soap, Patent No. 2,710,838 (A. J. Morway & W. H. Brugmann, Jr., assignors to Esso Research & Engineering Co.) A lubricating grease composition consisting essentially of a lubricating oil thickened to grease consistency with metal soap, said soap comprisiug a sufficient amount to substantially improve thixotropy of the grease, amounting to at least 25% by weight of said soap, of an alkali metal soap of saturated aliphatic polycarboxylic acid material having an average molecular weight in the neighborhood of 1000 and having an average of at least 1.75 and not substantially more than 2 carboxyl groups per molecule.

Greases Thickened with Phenylene Diamides, Patent No. 2,709,157 (B. W. Hotten, assignor to California Research Corp.) A grease composition comprising a major proportion of an oil of lubricating viscosity and a small amount, sufficient to thicken the lubricating oil to the consistency of a grease, of aliphatic acyl phenylene diamine containing a total of from 18 to 30 carbon atoms and not more than one acyl group attached to a nitrogen atom.

Lubricant Containing Reaction Products of Conjugated Unsaturated Ketones with Organic Sulfhydryl Compounds, Patent No. 2,709,682 (E. C. Knowles, H. D. Kluge & J. E. Fields, assignors to The Texas Co.) A lubricant composition comprising a major amount of a mineral lubricating oil and a minor amount sufficient to improve the anti-corrosion characteristics thereof of a compound obtained by reacting an aliphatic alpha-beta unsaturated ketone and an organic sulfhydryl compound in a mol ratio of not more than about 1 to 3.

Tin Pot Oil Composition, Patent No. 2,710,272 (W. O. Cook, assignor to United States Steel Corp.) A tinpot oil consisting of a major portion of a mineral oil having a flash point greater than 500 F.; at least about 5% by weight of fatty oil selected from the group consisting of palm oil, castor oil, tallow, hydrogenated corn, cottonseed, coconut and fish oil; and at least 0.25% by weight of stannous chloride.

Aryl-Urea Thickened Greases, Patent No. 2,710,839 (E. A. Swakon & C. G. Brannen, assignors to Standard Oil Co.) A lubricant grease comprising essentially a silicone polymer oil in the lubricating oil viscosity range thickened with from about 5 to about 70% by weight of N-benzoyl-p-aminobenzoic acid.

Aryl Urea-Thickened Greases, Patent No. 2,710,840 (E. A. Swakon & C. G. Brannen, assignors to Standard Oil Co.) A lubricant grease comprising an oleaginous lubricant vehicle thickened to grease consistency with a mixture of arylureas.

Method of Preparing Substituted Urea-

Thickened Greases, Patent No. 2,710,-841 (E. A. Swakon & C. G. Brannen, assignors to Standard Oil Co.) The method of manufacturing a lubricant grease comprising a substituted urea-thickened lubricant vehicle which comprises producing in situ in a reaction medium comprising the lubricant vehicle of the grease substituted urea.

Synthetic Lubricating Composition, Patent No. 2,710,877 (D. W. Young, D. L. Cottle & L. K. Beach, assignors to Esso Research & Engineering Co.) As a new composition of matter, a synthetic lubricating oil composition having outstanding lubricating properties which comprises a complex ester.

Vapor-Phase Corrosion Inhibition with a Mixture of Inhibitors, Patent No. 2,711,360 (A. Wachter & T. Skei, assignors to Shell Development Co.) A corrosion-inhibiting composition of matter comprising a non-aromatic hydrocarbon ammonium nitrite salt having a vapor pressure of at least about 0.0001 mm. Hg at 21 C. and a carboxylic acid salt of an amine, said carboxylic acid being a hydrocarbon carboxylic acid having between one and two carboxyl radicals, containing less than 19 carbon atoms per molecule and having a dissociation constant between about 10^{-8} and about 10^{-6}, said amine containing not more than about 25 carbon atoms, the weight ratio of said nitrite salt to said carboxylic acid salt being between about 20 and about 0.3.

Corrosion Inhibiting Composition, Patent No. 2,711,374 (J. I. Wasson & B. W. Geddes, assignors to Esso Research & Engineering Co.) A corrosion inhibiting composition for fine machinery comprising a major proportion of a dialkyl ester of dibasic aliphatic carboxylic acid as a lubricating oil, about 1% by weight of oil-soluble petroleum sulfonate, about 1% of degras, about 1% of pentaerythritol monooleate, about 0.5 to 0.6% of lecithin and about 0.5% of 2,6-ditertiary butyl paracresol.

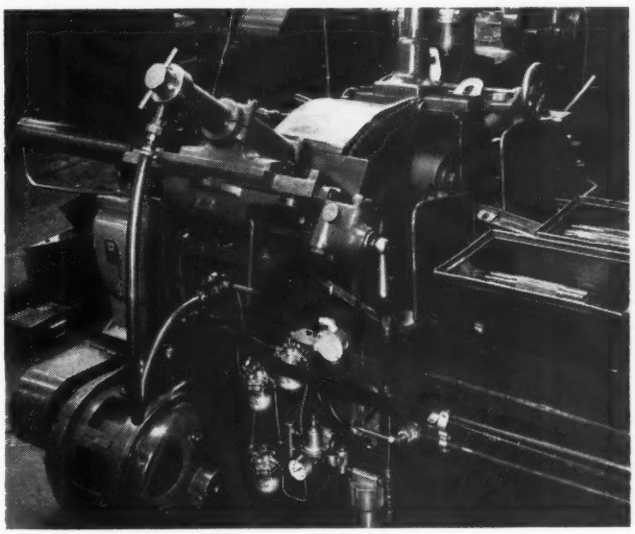
(Lube Abstracts, from p. 411)

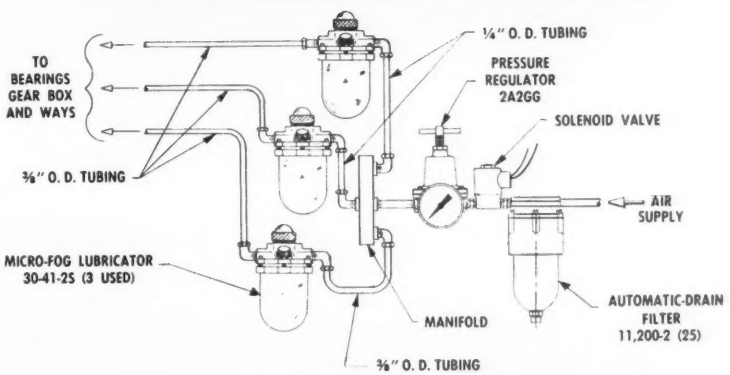
active media upon this portion of the cutting work. Cutting fluid used: Nonpolar kerosene with additions of heptyl and cetyl alcohols, and caprylic and palmitic acids dissolved in it. Results of experiments; their interpretation; conclusions to be drawn. Suitability of authors' method for studies of the effect of active liquid media upon processes of metal cutting. (Order No. 2394, Price $2.80)

Activated Lubricants for the Cold Drawing of Tube Stock, by V. F. Mal'tsev, F. M. Gertsman & M. P. Zheldak; "Stal," Vol. 8, 1948. pp. 147-152; 3 figs., 3 tables, 2,200 words. Experimental study of cold drawing lubricants improved by activating additives. Data

Norgren MICRO-FOG
completely lubricates centerless grinder with only 12 drops of oil per minute

Here's another typical example of how Norgren Micro-Fog provides more efficient, automatic lubrication with minimum costs. Micro-Fog, replacing a pump recirculating system on the centerless grinder, uses only 12 drops of oil per minute to lubricate the drive bearings, thrust bearings on wheel spindle, journal bearings, gear change box, journal and thrust bearings on back up wheel, and two sets of ways. A unique system of chevron grooving in drive shaft bearing aids in Micro-Fog distribution.





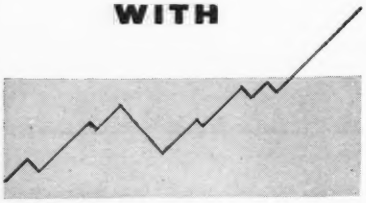
THE NORGREN MICRO-FOG LUBRICATION EQUIPMENT

For complete details on this Micro-Fog application write for Blueprint MF 15 or phone the Norgren representative listed in your telephone directory classified section under Norgren Pneumatic Products.

C. A. Norgren CO.
3434 So. Elati, Englewood, Colo.

TO KEEP COSTS DOWN

KEEP PRODUCTION UP WITH

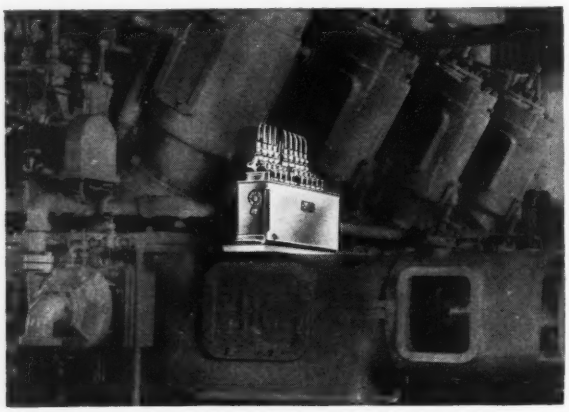


MANZEL

FORCE FEED LUBRICATION

Pressure Application — Exact Amounts — Accurately Timed

Manzel Force Feed Lubricators insure efficient machinery operation by lubricating automatically. No stops for hand oiling — or because of breakdowns caused by faulty lubrication. They



quickly pay for themselves through savings in down time, labor and lubricants.

These sturdy, dependable lubricators can be installed on new or existing equipment. Write for details.

Professionally qualified engineering representatives throughout the country.

Manzel

DIVISION OF

HOUDAILLE-HERSHEY CORP.

273 BABCOCK ST., BUFFALO 10, N. Y.

on decrease of drawing force and on improvement of other drawing characteristics obtained with engine oil plus naphthenic soap, or acid and paraffin wax in the cold drawing of carbon steel tubes. Cold drawing of locomotive tubes in a single pass; data on defectives, die wear, etc. (Order No. 2418, Price $4.40)

(Current Literature, from p. 401)

lists physical specifications, as well as the results of exhaustive tests, and includes price and ordering information. (The Alpha Molykote Corp., LE-11/6, 65 Harvard Ave., Stamford, Conn.)

"Molybdenum Catalysts for Industrial Processes," reviews reactions which research and pilot plant work indicate may be advantageously catalyzed by molybdenum compounds, as well as commercial processes now using molybdenum catalysts. One section of the booklet is devoted to the factors that must be considered in choosing a specific molybdenum catalyst, i.e., compounds that have been used or may be useful, the oxidation state, supports for the catalyst, promoters which may improve performance of the molybdenum catalysts, addition of other catalytically-active compounds, and the methods of manufacture. There is appended a list of 25 references of value to anyone seeking more complete information on the subject. (Climax Molybdenum Co., LE-11/6, Dept. L, 500 Fifth Ave., New York 36, N. Y.)

"Facts About Titanium," contains a list of the commonly available titanium alloys and their compositions, forming and welding methods, heat treatment and machining information; as well as current and projected prices and other pertinent data. A brief comparison of titanium properties with those of a stainless steel and aluminum alloy is also included. (Arthur D. Little, Inc., LE-11/6, 30 Memorial Dr., Cambridge 42, Mass.)

Master Pneumatic Catalog. In addition to comprehensive listings of the many sizes and types of air filters and lubricators they pro-

(Continued on p. 431)

Before you buy

LITHIUM HYDROXIDE

Research the Source

Four factors make Lithium Corporation your best source of supply:

1. ***COMPANY-OWNED ORE DEPOSITS AND CONCENTRATION FACILITIES.***
   Lithium Corporation's position with respect to raw ore reserves is second to none.
2. ***COMPLETE CHEMICAL PROCESSING AND ELECTROMETALLURGICAL PLANTS.***
   Indicative of future planning in terms of meeting the world's needs for lithium is the company's new $7,000,000 chemical plant which went on stream this year.
3. ***RESEARCH AND PRODUCT DEVELOPMENT FACILITIES.***
   A newly formed Department of Product Research and Development has been created to develop new uses and markets for lithium compounds.
4. ***EXCLUSIVE ATTENTION TO LITHIUM.***
   Lithium Corporation has developed lithium into more forms for more commercial uses than any other processor in the field. Available now, experimentally or commercially, are six salts, seven forms of metal, and nine special compounds.

To be sure . . . research the source.

. . . trends ahead in industrial applications for lithium

LCA **LITHIUM CORPORATION OF AMERICA, INC.**
2585 RAND TOWER
MINNEAPOLIS 2, MINN.

MINES: Keystone, Custer, Hill City, South Dakota • Bessemer City, North Carolina • Cat Lake, Manitoba • Amos Area, Quebec • BRANCH SALES OFFICES: New York Pittsburgh • Chicago • CHEMICAL PLANTS: St. Louis Park, Minnesota • Bessemer City, North Carolina • RESEARCH LABORATORY: St. Louis Park, Minnesota

E. S. P. S., Inc.

The following Positions-and-Engineers Available information is furnished by **Engineering Societies Personnel Service, Inc.,** a non-profit placement service sponsored by **ASLE,** AIEE, AIME, ASCE, ASME, ESD, ECSF, ESM, ISPE, SNAME, and WSE. Replies should be addressed to the key numbers indicated.

If placed in a position as a result of these listings, applicant agrees to pay an established moderate placement fee which is used to defray the expenses of this non-profit, self-supporting service (rates available upon request).

ASLE members may submit Engineers Available advertisements, limited to 35 words, for insertion at no charge in appropriate journals; attach typed resume for ESPS confidential files.

A weekly ESPS bulletin of positions open is available by subscription (rates on request).

Direct all correspondence to **ESPS, Inc.,** at one of the following addresses:

8 W. 40th St. .....New York City
100 Farnsworth Ave. .....Detroit
84 E. Randolph St. .....Chicago
57 Post St. .....San Francisco

ENGINEERS AVAILABLE

Maint. (357-LE) 31, ME; 5 yrs. resp. for road maint. fleet, constr. eqpt. & rebuild shop; West; $7,500.

Chief Engr. (358-LE) 37, ME; 9 yrs. resp. for piping, htg. apparatus, steam power & water treating plants; installed eqpt. & wrote specs. in process industries; 2 yrs. supv. repair work of machy., engine overhaul & refrig. eqpt.; 1 yr. tool designing; US; $10,500.

Plant Engr. (359-LE) 30, AE; 4 yrs. plant engrg. covering layout, dev., maint. & time studies on various types of mech. eqpt. & power plant supv.; 1½ yrs. production eqpt. engr.; 6 mos. sales of mech. power transmissions eqpt.; Midwest; $8,000.

Chief Engr. (360-LE) 63; 8 yrs. charge of maint. of special machy. & presses; 1 yr. consulting work on mech. eqpt.; 5 yrs. supt. in a ship yard; 1 yr. gen'l. machine shop supt.; Midwest or West; $7,500.

Ass't. Process Engr. (361-LE) 31, PhD Chem. Engrg.; 5 yrs. process engrg. & dev. for refinery; Non-citizen; US; $6,000.

Chief Engr. (362-LE) 35, Chem. Engr.; 4 yrs. supv. 8 engrgs. & drfts. for maint. dept. in plastics field; 5 yrs. chem. engr. to investigate possible refinery processes; Midwest; $9,000.

Sales Mgr. (363-LE) 35, ME; 3 yrs. sales, trans. eqpt. to oil industries; 3 yrs. sales ind. lubr. products; 1 yr. inst. of foundry eqpt. & machy.; 3 yrs. aircraft maint.; Midwest; $6,500.

Process Engr. (364-LE) 40, Ch. Engr.; 5½ yrs. process engr. & insp. of refinery eqpt., plant problems, trouble shooting & combustion engrg. on htg. eqpt.; Midwest; $500.

Maint. (365-LE) 28, ME; 6 yrs. plant engr. directing maint. of machy. & eqpt.; 2 mos, drftg. & des. on hvy. road eqpt. & hydraulics; US; $7,200.

Sales Engr. (366-LE) 32, IE; 4 yrs. ind. engrg. covering plant layout, matl. handling, methods & time study; definitely interested in sales; Chicago; $6,000.

Sales Engr. (367-LE) 32, IE & ME; 1¾ yrs. appl. analysis & sales functions of aviation, farm & oil sealing eqpt.; 2 yrs. 4 mos. field & combustion engr. on htg. eqpt.; Midwest; $6,500.

Lubr. Supv. (368-LE) 34; 10 yrs. supv. oilers, specify tests, schedule changes, order lubricants & recommend improvements, set up complete lubr. program; $500.

Lubr. & Sales Engr. (369-LE) 57; 18 yrs. lubr. & sales engrg. in all ind. & trans. fields; 8 yrs. military public relations, personnel, engrg. & command; West; Sal. open.

POSITIONS AVAILABLE

D-2433, Elect. Engr. With bkgd. of plant des. with consultants; should be familiar with operating requirements of large process plants similar to Aeg.; will initially act as consultant between arch. & contractor during constr. & be intergraded into operations as Sr. EE Power; Midwest.

D-2528(b), Lubr. Engr. In large plant; Jr. ME or Chem. Engr. to assist in establishing lubr. procedures; Midwest; to $470.

D-2600, Lubr. Engr. 24-34; engrg. degree & qualified by exp. to supv. oilers, specify tests of lubricants used, schedule changes of lubricants, order special lubricants & deal with sales engrg. on specialized lubr. requirements; Midwest.

C-4047, Tech. Editor. ME, EE, IE, or AE; 25-35; 3 plus yrs. exp. in tech. writing in control or instr. field; duties: Ass't. Editor on tech. society's publication staff, handling original articles, field reports, re-write, evaluating matl., & planning complete monthly issues on automatic controls & automation; occasional traveling; for Society of Tech.; Pennsylvania; $7-9,000.

C-4067, Sales Engr. ME; to 35; 2 plus yrs. exp. in sales, application, or service of conveyors; duties: calling on conveyor eqpt. mfrs. selling line of ind. rubber products; car req'd.; for mfr. of Ind. Rubber; Chicago; empl. will neg. fee.

C-4068, Field Engr. ME; 1 plus yrs. exp. in test or des. of diesels or engines; know: dynamometers, helpful; duties: supv. endurance tests of diesel engines & report writing; travel 30-50%; for test. indus.; Sal. $400 plus overtime & exp.; Loc. Chgo. hdqrs.; empl. will neg. the fee.

C-4072, Sales Cutting Oils. Age 30 plus; 3 yrs. exp. in sales of oils to ind.; know: cutting oils & applications; duties: selling industrial oils to industry in gen'l.; car furnished; for refiners of indust. oils; $300/mo. plus 4% comm. (abt. $8,000 first yr.); Chicago.

C-4073, Chemist. Chem.; age to 35; rec. grad, or better; duties: lab. chemical analyses & test work; for mfr. of cosmetics; $93.00/week; Chicago.

C-4074, Power Engr. BS; 30-35; 5 yrs. exp. control eqpt. steam generation, instrumentation; duties: demonstrating improved methods of operating & maint. steam generating eqpt., prepare & conduct instruction courses for firemen & examine for various ratings; adapt eqpt. for automatically controlling processes; consult. on steam, elect., air & hydraulic eqpt.; 30% travel; for mfr. of corrugated containers; $6,500-8,500/yr.; Indiana.

C-4090, Chemist. AG in Chem.; age to 35; rec. grad. or better; must be US citizen; duties: analytical work in control lab.; for refinery of pet.; $389-450; Calumet area; empl. will neg. the fee.

C-4091, Chem. Engr. Chem. Engr.; age to 30; rec. grad, or better; must be US citizen; duties: tech. serv. & refinery process production control; for refinery of pet.; $389-450; Calumet Distr.; empl. will neg. fee.

C-4096, Field Engrs. Pet. Chem. or ME; age to 35; 2 plus yrs. in field work, drftg., des., production or res.; duties: training as field engr. investigating hazards & other engrg. factors in oil, gas, & chem. plants; for Insurance Underwriters of process ind.; to $6,000/yr.; Chicago hdq.; 20% travel; empl. will pay the fee.

C-4097, Statistical Analyst. Statistics grad.; age to 35; know marketing, helpful; duties: resp. for mixing warehouse program requiring preparation of statistics for the analysis of inventories, orders, shipments & sales distr. to maintain inventories required at various locations; for mfr. of rubber; $425-450/mo.; Ohio.

C-4108, Project Engr. ME, age to 30; 3 plus yrs. exp. in plant project or constr. work; know coordinating purchasing & engrg.; duties: project engrg. on plant eqpt., remodeling or constr.; for mfr. of metal cleaning eqpt.; $450-550/mo.; Calumet distr.; empl. will neg. fee.

C-4109, Stress Analyst. ME; exp. in piping systems analysis; know: math & mechanics; duties: piping systems, stress analyses on high temperature & high pressure systems; for mfr.; sal. $6,500-8,500; Pennsylvania; empl. might neg. fee.

Make plans NOW!

11th
ASLE Annual Meeting

Hotel William Penn
Pittsburgh

April 4-5-6, 1956

(Current Literature, from p. 428)
duce, Master Pneumatic has included sections devoted to facts and figures on the savings made possible by correct air filtration and lubrication at every air drop ahead of every air tool. A new Master Hydro-Jector is shown which automatically empties filters and other accumulators of trapped liquids and sludges with completely positive, non-sticking action; the lifetime sintered porous bronze filter element and its many applications to air, water, gas, and oil filtration is described; and the fool-proof constant, proportional oil feed lubricator which adjusts itself to varying air flow is featured. Filter and lubricator installation and maintenance are covered in detail, and a dimensions sheet and parts list complete the catalog. (Master Pneumatics, Inc., LE-11/6, 20432 Sherwood, Detroit 34, Mich.)

"Fluoroflex-T" Laminated Pipe. A new four-page bulletin describes the physical and chemical properties of Fluoroflex-T laminated pipe, the Resistoflex name for pipe manufactured from woven glass impregnated with Teflon resin; other data includes piping specifications, a detailed description of flanging and coupling the pipe in the field with a special tool, as well as suggested applications. (Resistoflex Corp., LE-11/6, 39 Plansoen St., Belleville, N. J.)

"Kel-F Fluorocarbon Oils, Waxes & Greases," covers the chemical structure, specifications, properties, applications, and general description of a new group of fluorocarbon oils, waxes, and greases being distributed by The M. W. Kellogg Co. Based on the extremely stable polychlorotrifluoroethylene molecule, these polymer products have been designed for critical spots where performance is vital; among the applications suggested are: hydraulic pumps, pump fluids, potting and sealing waxes, damping fluids, heat transfer media, permanent lubricants for instruments and clocks, and synthetic lubricant blends. The booklet discusses in detail: color and clarity, viscosity, specific gravity, surface tension, flammability, vapor pressure, dielectric properties, acidity, chemical stability, solubility, and lubricity, among other qualities of Kel-F waxes, oils, and greases. (The M. W. Kellogg Co., LE-11/6, P. O. Box 469, Jersey City 3, N. J.)

(Section News, from p. 396)
TWIN CITIES, September. A. F. Lyster, Socony Mobil Oil Co., presented a paper entitled "Heat Treatment of Steel," and its relation to petroleum products used. (Submitted by C. D. Johnson, Sec'y.)

WHEELING, September. C. A. Bailey, U. S. Steel Corp., presented a paper entitled "New Test Procedures," covering new testing procedures and methods employed for the evaluation of oils in greases.

October, "Additives in Lubricants," by D. Espey, Esso Standard Oil Co. (Submitted by S. J. Litten, Sec'y-Treas.)

(Book Reviews, from p. 388)
Separate chapters then follow, each treating a different soap base grease. These chapters include aluminum, barium, calcium, lithium, sodium, lead, and strontium base lubricating greases. Subsequent chapters discuss miscellaneous soap greases, mixed base greases, complex soap lubricating greases, non-soap thickeners and fillers in greases and solid lubricants. Each of these chapters gives a detailed description of the raw materials, the structure, the additives, and the preparation of the grease. The effects of the various constituents, the properties, and applications for the grease, follow with numerous subdivisions under each of these topics.

The remainder of the book includes sections on the analyses of lubricating grease, tests of lubricating grease and their significance, and applications of lubricating greases. Grease analysis covers primarily explanations of standard chemical test techniques such as the separation of the lubricating fluids and the determi-

UCON
TRADE-MARK
LUBRICANTS

for MISSISSIPPI CHEMICAL CORPORATION

POWER RECOVERY ENGINES in Mississippi Chemical's ammonia oxidation plant have operated on UCON synthetic Lubricants for *more than a year* at 460°F. without a shutdown. With petroleum oil, maximum operating temperature was 400°F., and the engines had to be dismantled every month or two for cleaning and carbon removal.

Higher temperatures mean more recovered power; elimination of down-time means higher production; and reduced maintenance means savings.

UCON Lubricants have outstanding resistance to sludging and carbonizing. Check them for power recovery engines, compressors, vacuum pumps—and for general industrial lubrication. Write today for complete information.

CARBIDE AND CARBON CHEMICALS

Carbide and Carbon Chemicals Company
A Division of
Union Carbide and Carbon Corporation
UCC
30 East 42nd Street, New York 17, N. Y.
"Ucon" is a registered trade-mark of UCC.

ASLE DIRECTORY

NATIONAL OFFICERS

President ..... J. W. Hopkinson, Penn-Petroleum Corp.
Vice-President at Large ..... W. Deutsch, The Lectroetch Co.
Secretary ..... E. R. Booser, General Electric Co.
Treasurer ..... W. H. Fowler, Jr., The Pure Oil Co.
Administrative-Secretary ..... W. P. Youngclaus, Jr., ASLE National Office
Chairman, Pres. Council ..... J. Boyd, Westinghouse Electric Co.
Vice-President, Canadian ..... G. R. Armstrong, B. Greening Wire Co., Ltd.
Vice-President, Midwestern ..... E. D. Harkins, Sr., The Farval Corp.
Vice-President, Eastern ..... J. O. McLean, Reynolds Metals Co.
Vice-President, Western ..... M. H. Sperling, Richfield Oil Corp.

NATIONAL DIRECTORS

A. E. Cichelli, Bethlehem Steel Co. ..... W. Lasky, Gulf Mobile & Ohio R.R. Co.
J. L. Finkelmann, The Warren Refg. & Chem. Co. ..... J. D. Lykins, Wheeling Steel Corp.
J. H. Fuller, E. I. duPont deNemours & Co. ..... W. H. Millett, Carbide & Carbon Chemical Co.
R. H. Josephson, Cleveland Graphite Bronze Co. ..... C. R. Schmitt, E. F. Houghton & Co.

SECTION OFFICERS

	CHAIRMAN	VICE-CHAIRMAN	SECRETARY	TREASURER
Baltimore	W. W. Witmer	J. E. Buchanan	R. L. Humphreys	C. J. Devries
Boston	H. A. Wilson	H. G. Senning	G. T. Collatz	R. S. Jackman
Buffalo	A. Brownell	V. Steele	L. E. Locke	C. L. Miller
Chicago	A. B. Wilder	R. G. Grothus	J. N. Wadell	J. N. Wadell
Cincinnati	C. A. Garrison		M. D. Upper	M. D. Upper
Cleveland	A. O. Anderson	E. F. Rost	J. W. Hurley	G. L. Smith
Connecticut	F. M. Dohl	P. Faxon	N. E. Shirk	N. E. Shirk
Dayton	E. C. Briggs	H. L. Sellers	A. H. Lipton	H. J. Martin
Detroit	R. F.Urso	J. A. Brady	T. Cabba	C. F. Cowley
Fort Wayne	J. W. Buckner	C. R. Griffith	J. M. Olson	J. M. Olson
Houston	K. A. Danskin	J. H. Moran	A. W. Elrod	R. DuPont
Indianapolis	J. R. McCoy	L. E. Danford	C. M. Marlatt	C. M. Marlatt
Kansas City	D. L. McCormick	W. R. Johnston	E. R. Allgeyer	C. L. Austin
Kingsport	J. E. Fleenor	L. Hale	H. Woods	H. Woods
Los Angeles	R. C. Dishington	T. R. Costello	G. Jepson	G. Jepson
Louisville	R. T. Knight	C. O. Wittig	R. I. Wilding	R. I. Wilding
Milwaukee	W. E. Elliott	J. A. Gramling	J. H. Berg	V. A. Weiss
Montreal	A. R. Scott	R. D. Poole	J. H. Whyte	J. H. Lemeilleur
New York	O. W. Wuerz	D. B. Gordon	H. Cunha	H. D. Lewis
N. California	L. M. Tichvinsky	R. H. Decker	A. C. West	J. K. Longmuir
Ontario	W. B. Dembner	J. F. Parker	R. E. Sparrow	G. F. Hill
Philadelphia	J. L. Beatty	R. W. Clark	W. P. Finlay	K. S. Smiley
Pittsburgh	L. B. Sargent	W. G. Ritter	J. L. Duchene	M. Parker
Saginaw Valley	N. Pagels	J. R. Campbell	J. W. Mestrezat	J. Dalton
St. Louis	H. W. McCulloch	G. W. Schall	L. F. Hartmann	G. Gergeceff
Syracuse	R. Buyea	H. E. Kaye	E. J. Naughton	T. F. Dundon
Twin Cities	R. O. Erickson	D. L. Heimes	C. D. Johnson	J. B. McFail
Wheeling	L. R. McDonald	C. Billingsley	S. J. Litten	S. J. Litten
Youngstown	J. N. Hocke	D. E. Whitehead	J. A. Weber	J. R. Lemmon

ADDRESSES OF SECTION SECRETARIES

Baltimore ..... R. L. Humphreys, Bethlehem Steel Corp., 22 Eastship Rd., Baltimore 22, Md.
Boston ..... G. T. Collatz, 473 Washington St., Wellesley, Boston 81, Mass.
Buffalo ..... L. E. Locke, Battenfeld Grease & Oil Co., P. O. Box 144, N. Tonawanda, N. Y.
Chicago ..... J. N. Waddell, Henry H. Cross Co., 122 S. Michigan Ave., Chicago 3, Ill.
Cincinnati ..... M. D. Upper, Sun Oil Co., P. O. Box 7, Sta. F., Cincinnati 4, Ohio
Cleveland ..... J. W. Hurley, Ford Motor Co., 17601 Brookpark Rd., Cleveland, Ohio
Connecticut ..... N. E. Shirk, 47 Prospect St., Waterbury, Conn.
Dayton ..... A. H. Lipton, 701 Lexington Ave., Dayton 7, Ohio
Detroit ..... T. Cabba, Sinclair Refg. Co., 5060 Lakewood, Apt. 6, Detroit 13, Mich.
Fort Wayne ..... J. M. Olson, Sun Oil Co., 4900 N. Clinton St., Fort Wayne 3, Ind.
Houston ..... A. W. Elrod, Gulf Oil Co., P. O. Box 2140, Houston, Tex.
Indianapolis ..... C. M. Marlatt, Neff Engrg. Co., P. O. Box 7361, Indianapolis, Ind.
Kansas City ..... E. R. Allgeyer, The Marley Co., 222 W. Gregory, Kansas City, Mo.
Kingsport ..... H. Woods, The Mead Corp., W. Main St., Kingsport, Tenn.
Los Angeles ..... G. Jepson, Bowser, Inc., 2843 W. 7th St., Los Angeles, Calif.
Louisville ..... R. I. Wilding, 646 Lindell Ave., Louisville 11, Ky.
Milwaukee ..... J. H. Berg, 2537 N. 41 St., Milwaukee 10, Wisc.
Montreal ..... J. H. Whyte, British American Oil Co., 606 Catheart St., Montreal, P. Q., Canada
New York ..... H. Cunha, National Biscuit Co., 449 W. 14th St., N. Y. 14, N. Y.
N. California ..... A. C. West, California Research Corp., 576 Standard Ave., Richmond 1, Calif.
Ontario ..... R. E. Sparrow, Shell Oil Co. of Canada, Box 58, Sta. C, Hamilton, P. O., Canada
Philadelphia ..... W. P. Finlay, Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.
Pittsburgh ..... J. L. Duchene, Baldwin-Lima-Hamilton Corp., 567 Union Trust Bldg., Pitts., Pa.
Saginaw Valley ..... J. W. Mestrezat, 2762 Thomas St., Flint 4, Mich.
St. Louis ..... L. F. Hartmann, Olin-Mathieson Chemical Corp., East Alton, Ill.
Syracuse ..... E. J. Naughton, 182 Clyde Ave., Syracuse, N. Y.
Twin Cities ..... C. D. Johnson, Twin Cities Test. & Engrg. Lab., 2440 Franklin Ave., St. Paul 4, Minn.
Wheeling ..... S. J. Litten, Sun Oil Co., 910 Pearl, Martins Ferry, Ohio
Youngstown ..... J. A. Weber, 166 N. Middle St., Columbiana, Ohio

NATIONAL COMMITTEE CHAIRMEN

Awards ..... E. G. Guenther, Tennessee Eastman Corp.
By-Laws ..... A. F. Brewer, Consultant
Editorial ..... R. K. Gould, The Texas Co.
Education ..... B. G. Rightmire, Massachusetts Institute of Technology
Exhibit Arrangements ..... J. D. Lykins, Wheeling Steel Corp.
Finance ..... J. W. Peterson (Chairman), Standard Oil Co. (Ind.)
W. H. Fowler, Jr. (Chairman Ex-Officio), The Pure Oil Co.
Handbook Advisory ..... H. E. Mahncke, Westinghouse Research Labs.
Historian ..... W. G. Fatch, Carnegie-Illinois Steel Corp.
Industrial Membership ..... W. P. Youngclaus, Jr., ASLE National Office
Industry Relations ..... J. P. Critchlow, Gulf Oil Corp.
Membership & Admission ..... B. T. Harding, Midwest Oil Co.
National Meeting (Annual—Pittsburgh) ..... J. P. Critchlow, Gulf Oil Corp.
National Meeting Manual ..... A. S. McNeilly, Esso Standard Oil Co.
New Sections ..... W. P. Youngclaus, Jr., ASLE National Office
Nominations ..... W. E. Campbell, Brush Labs. Co., Div. of Clevite Corp.
Program (Annual Meeting—Pittsburgh) ..... D. W. Sawyer, Aluminum Co. of America
Research & Projects ..... E. M. Glass, Hq. Wright Air Development Center

TECHNICAL COMMITTEE CHAIRMEN

General Technical ..... E. R. Booser, General Electric Co.
Bearings & Bearing Lubrication ..... A. A. Raimondi, Westinghouse Electric Co.
Engine Lubrication ..... N. C. Penfold, Southwest Research Institute
Fluids for Metal Working ..... E. L. H. Bastian, Shell Oil Co.
Gears & Gear Lubrication ..... S. R. Calish, Jr., California Research Corp.
Hydraulics & Hydraulic Machinery ..... G. B. Miller, Racine Hydraulics & Machinery, Inc.
Lubricant Reclamation & Disposal ..... A. B. Two, Ford Motor Co.
Lubrication Equipment ..... E. M. Higgins, Master Lubricants Co.
Lubrication Fundamentals ..... D. Godfrey, California Research Corp.
Physical Properties of Lubricants ..... M. L. Langworthy, The Texas Co.
Principles & Practices of Economic Lubrication ..... K. S. Smiley, E. I. duPont deNemours & Co.

nation of thickeners, free fatty acids, certain additives, and other materials. Under test methods the author describes more than 25 different tests which are intended to characterize some performance or inspection characteristic of a grease. These tests range from consistency tests such as penetration procedures, through oxidation and separation evaluations, to the various bearing and extreme pressure tests most commonly used. The first part of the chapter on grease applications is devoted to dispensing and feeding equipment. The next part contains general guides for lubricating grease selection for various applications such as ball and roller bearings, multi-purpose greases, chassis lubricants, and others.

The value of the book as a reference work is enhanced by an extensive alphabetical index. However, this reviewer feels that a more detailed table of contents would have helped considerably in showing the organization of information within each rather lengthy chapter.

(Cover Story, from p. 404)

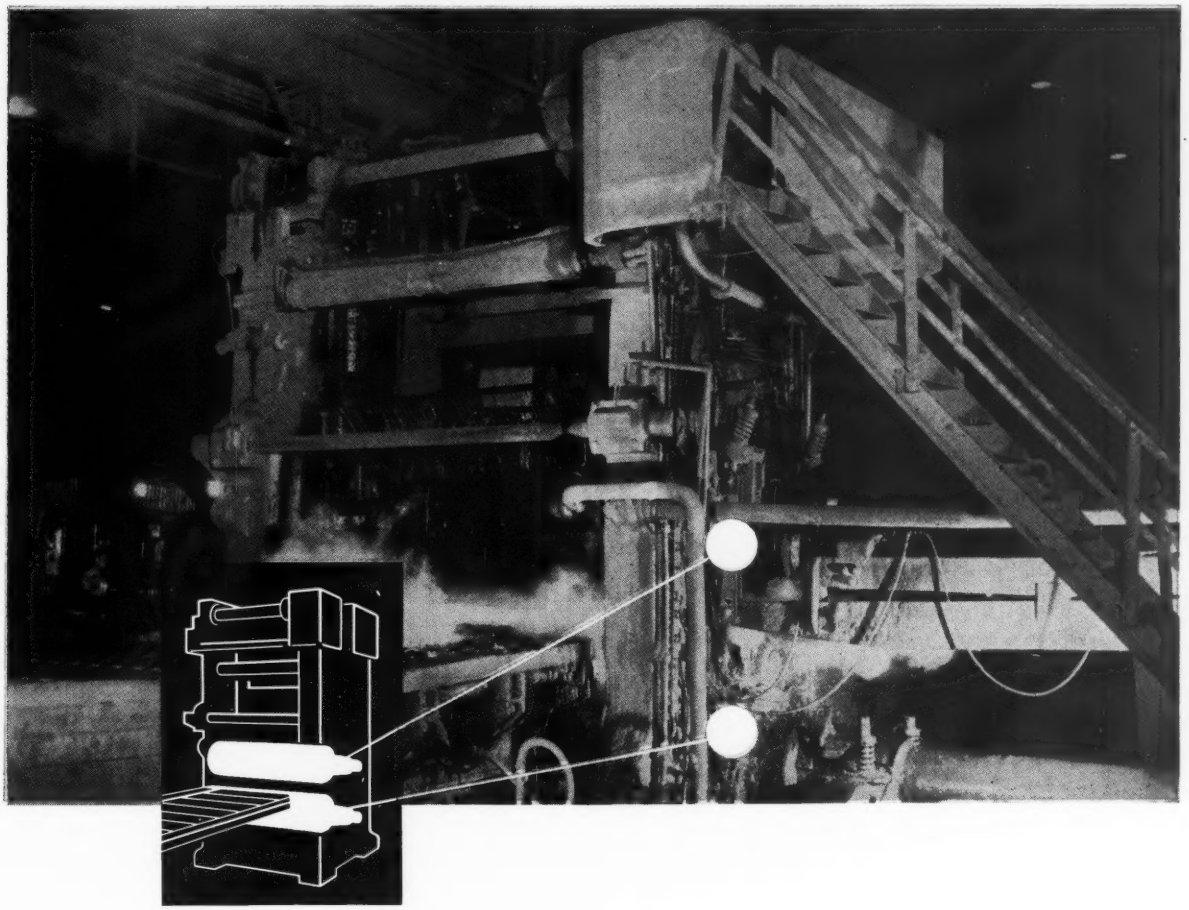
comes so finely dispersed in the water that the two form a homogeneous liquid. Such an intimate mixture has suggested "solubility" to its users for many years. This stable oil-water emulsion gives longer life to the cutting edge and expedites a variety of machining operations that would be difficult to perform without it. Soluble cutting fluids have made many turning, drilling, grinding, broaching, milling, and shaping jobs easier, faster, and more precise. (Submitted by Esso Standard Oil Co.)

(New Products, from p. 417)

nance purposes is the Gits Lubrikit, a conveniently-boxed assortment of 95 oil cups of 29 different types. Each type of oiler comes in its own separate bin within the kit; contents of each bin are fully and clearly described on the inside of the cover. (Gits Bros. Mfg. Co., LE-11/6, 1846 S. Kilbourn Ave., Chicago 23, Ill.)

Float Level Indicator. A hermetically-sealed float level indicator (Model F-8685), weighing 0.9 ounces, for control or indication of levels of various liquids, is

Lubricating roll necks is no easy job



Lubricating the roll necks of a steel mill calls for a lubricant that will resist high temperatures. The lubricant must also function in the presence of steam, water, mill scale and other abrasive materials. It has to cushion great shock loads and cling tenaciously to the bearings it protects. It must last a long time . . . and it must be economical in use.

Atlantic Lubricant 10 performs exceptionally well in this service. It is being used in a pressure system on the mill illustrated, at the Lukens Steel Company in Coatesville, Pa., for the lubrication of roll neck bearings, pinion and spindle bearings.

Selecting the correct lubricant for the job is simplified when you call in your Atlantic Lubrication Engineer. He is a man with years of on-the-job knowledge of heavy industrial lubrication requirements of all kinds.

Why not see for yourself the value of Atlantic service? Just write, wire or phone the office nearest you for full information. The Atlantic Refining Company, Dept. L-12, 260 South Broad Street, Philadelphia 1, Pa.

PROVIDENCE, R. I.
430 Hospital Trust Bldg.

SYRACUSE, N. Y.
Salina and Genesee Sts.

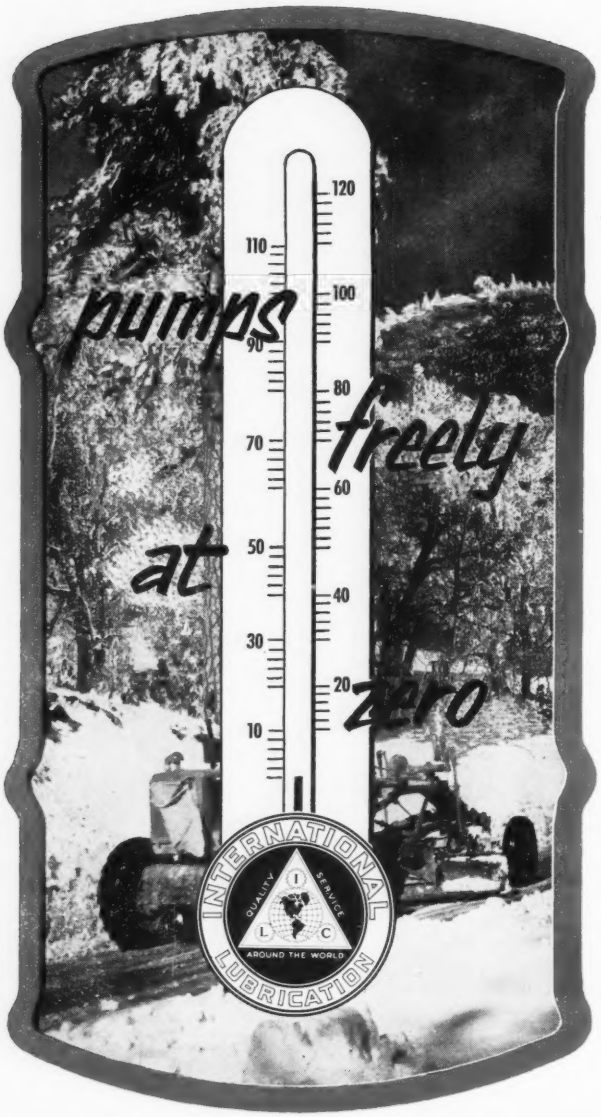
READING, PA.
First and Penn Aves.

PITTSBURGH, PA.
Chamber of Commerce Bldg.

CHARLOTTE, N. C.
1112 South Boulevard

ATLANTIC

LUBRICANTS • WAXES
PROCESS PRODUCTS



INLUCITE 21, International's lithium-base, multi-purpose grease, pumps freely when other greases freeze. The amazing pumpability of **INLUCITE 21** has been field-proved by fleet owners, service station operators and farmers from coast to coast.

In wheel bearings, water pumps, universal joints, shackles and other grease-lubricated bearings, this free-flowing multi-purpose grease outlasts every specialized grease it replaces.

INTERNATIONAL LUBRICANT CORP. • New Orleans

With Research Comes Quality,

With Quality Comes Leadership

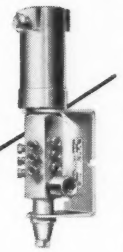
now available that has no exposed metal parts and may be used with solvents, oils, acids, and other chemicals. The single-pole, single-throw switch, rated at 10 watt load at 115 volts a.c., 0.5 amp resistive or inductive load at 28 volts d.c. (L/R — 0.026), has a 100,000 cycle minimum life and is enclosed in a nylon stem. Actuated by permanent magnets imbedded in the free float, eighteen-gauge nylon-jacketed leads extend through the threaded mount; it is 3.31 inches long (less leads) by 1.22 inches max. diameter. (Revere Corp. of America, LE-11/6, Wallingford, Conn.)

Super-Volume, Lever-Type Grease Guns. Two new super-volume lever guns equipped with rigid hydraulic coupler extension for contacting hydraulic fittings, or with flexible 12″ whip hose extension with button-head coupler for contacting button-head grease fittings, have been introduced that will deliver .17 ozs. per stroke, or 6 strokes per oz., using No. 1 cup grease at 70 F. Guns may be spring- or force-primed, hold 21 ounces of lubricant, and include filler nipple for fast, clean refilling from a filler pump or by suction. Of all-steel construction, rust-proofed, and finished in metallic gun-metal blue, the guns develop 2,500 lbs. max. pressure with ease and are designed especially for servicing bearings requiring large qauntities of lubricant. (Lincoln Engineering Co., LE-11/6, 5743 Natural Bridge Ave., St. Louis 20, Mo.)

Molykote Lubricants. Two new Molykote lubricants have been introduced: Type 165X and Type LOEX. Type 165X, an extreme bearing pressure open-gear lubricant, is a near-colloidal dispersion of Molykote Microsize in a viscous, tacky, and adhesive petroleum oil which has been rendered fluid by the addition of a volatile non-flammable diluent. Particularly recommended for construction machinery, elevator and escalator gear trains, mechanical presses, power shears, and winches, the film will not crack or peel off at temperatures as low as 0° F. Type LOEX is a diester

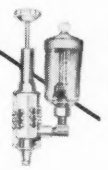
Lincoln ENGINEERING COMPANY
announces
THE Multi-Luber* SYSTEMS FOR POWER LUBRICATION

Applications Unlimited . . .

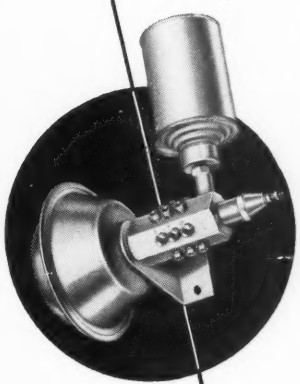


AIR-OPERATED

Adopted by leading Fleet and Bus Operators for automatic, controlled lubricant application each time driver applies the air brake. Complete Systems available in handy kits for simple installation. Air-Operated Multi-Luber Systems may be used wherever compressed air is available to reduce operating costs and increase efficiency on equipment ranging from transport trailers to automated, high speed lathes.



Where compressed air is not available, the air cylinder of the Multi-Luber can be replaced with a push button. These Manual Systems are available in kits for quick installation on tractors, farm implements, and a wide range of industrial machinery.



VACUUM-OPERATED

Multi-Luber Systems are also available for instantaneous, automatic lubrication of equipment ranging from light trucks to fork lift trucks, or for any application where vacuum is available. A touch of the control button, located wherever desired, delivers a pre-measured quantity of refinery-pure lubricant.

AND NOW . . . AVAILABLE ON 1955 model LINCOLN and MERCURY motor cars

Here is the newest and most revolutionary application of Lincoln's vacuum-operated Multi-Luber System. Now, purchasers of new Lincoln or Mercury motor cars have available instantaneous Power Lubrication at their own convenience. A mere touch of a button on the instrument panel provides the continuous pleasure of smoother car performance, greater steering ease and increased operating economy.

*Trade Name Registered Patent Pending

Lincoln Engineering Co. • 5743 Natural Bridge Ave., St. Louis 20, Mo.
PIONEER BUILDERS OF LUBRICATING EQUIPMENT FOR A QUARTER CENTURY

"Scrap and Pig for the Furnaces." Agnes Potter Lowrie depicts a variety of objects which will emerge Phoenix-like from the flames of the open hearth to new life as virgin steel: buck-toothed gears, a section of track, machine shop shavings, old tubing, stampings and, bulking equally large, rusty red pig.

The Fine Art of Steel Making

In sharp contrast to many industries, the basic ingredients of steel making have changed little, if any, over the years. How then has steel been able to spearhead America's industrial growth? How has it been able to produce more steel, better quality steel year by year?

Because steel men have worked constantly to improve the *mechanics* of steel making, as well as the metallurgy. And because steel's suppliers have parallelled every such improvement with an equal advance of their own.

Consider the materials which smooth the process of steel making — Ironsides Gear Shield lubricants. Heavy Gear Shield, once hand-paddled onto exposed gears, is now formulated with a solvent for quick spray application.

For encased gears, Gear Shield was produced in liquid form for pouring, pumping or timed-jet application. Later Ironsides was among the leaders in developing extreme pressure lubricants.

Today, so widespread is the acceptance of Ironsides lubricants that other makers have attempted to refer to their own products as "gear shield", even though Gear Shield is an Ironsides trade mark.

Ironsides is not mass production. We are the "Custom Tailors" of lubrication. Our special position is due in large part to our flexibility. We can — and do — formulate for individual applications and supply these formulas in any quantity from pails to tank cars.

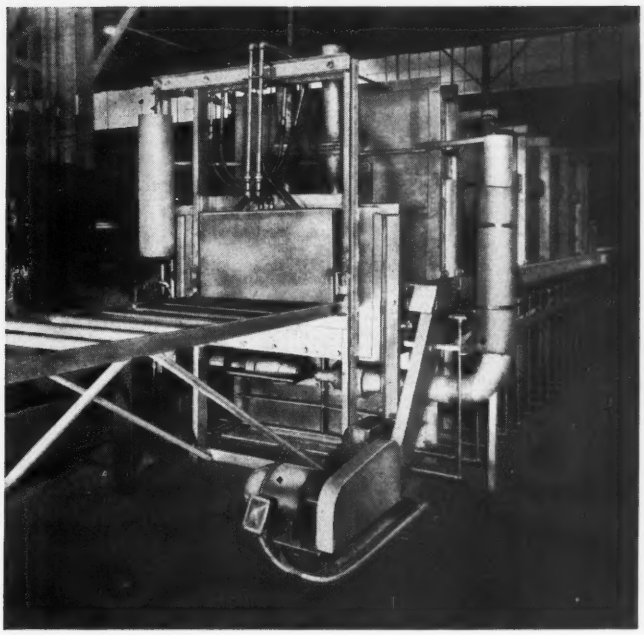
We like tough problems; we've solved a lot of them. For example, Palmoshield, replacement for palm oil and most important advance in lubrication since World War II. If you have a problem, we'd like to help lick it. A letter will summon one of our research engineers. The Ironsides Co., Columbus 16, Ohio.

SHIELD PRODUCTS

Ironsides

By the makers of Palmoshield • "the palm tree that grows in Ohio"

use 'dag' dry films for trouble-free lubrication



Here's how a Cleveland foundry proved the value of 'dag' *dry-film lubrication* in the operation of its continuous core-oven conveyor . . .

A 'dag' Colloidal Graphite dispersion was used in place of powdered graphite. The lubrication interval of conveyor chain and rollers was extended from *four* days to *sixty* days! In addition to tremendous lubricant and labor savings, conveyor wear has been notably reduced, carbon formation and flake-off eliminated.

This is typical of the extreme-temperature problems solved by 'dag' dispersions . . . problems with kiln cars and hot-strip mills . . . problems with *any* moving parts subjected to temperature extremes . . . problems where solvent action in degreasers or other situations destroys conventional lubricants.

You'll find a surprising number of ways to use 'dag' dispersions described in our free booklets. Write today for Bulletins No. 424-N7 and No. 435-N7.

Use 'dag' colloidal graphite to stretch maintenance dollars over 1400 percent!

Dispersions of molybdenum disulfide are available in various carriers. We are also equipped to do custom dispersing of solids in a wide variety of carriers.

ACHESON COLLOIDS COMPANY

PORT HURON, MICHIGAN

...also ACHESON COLLOIDS LIMITED, LONDON, ENGLAND

"LUBRIPLATE, THE OUNCE OF PREVENTION"

says
VULCAN IRON WORKS, INC.
of Chicago, Ill.

—a leading manufacturer of pile driving and extracting equipment

"For many years we have used LUBRIPLATE Lubricants for shop assembly, and have recommended them to our customers through your LUBRIPLATE Tag Plan. Our experience shows that if the proper lubricants are used from the beginning, there are fewer problems and parts replacements later. We consider LUBRIPLATE to be the best possible ounce of prevention."—
H. G. Warrington, Vice-Pres.

REGARDLESS OF THE SIZE AND TYPE OF YOUR MACHINERY, LUBRIPLATE GREASE AND FLUID TYPE LUBRICANTS WILL IMPROVE ITS OPERATION AND REDUCE MAINTENANCE COSTS.

LUBRIPLATE is available in grease and fluid densities for every purpose... LUBRIPLATE H.D.S. MOTOR OIL meets today's exacting requirements for gasoline and diesel engines.

For nearest LUBRIPLATE distributor see Classified Telephone Directory. Send for free "LUBRIPLATE DATA BOOK"... a valuable treatise on lubrication. Write LUBRIPLATE DIVISION, Fiske Brothers Refining Co., Newark 5, N. J. or Toledo 5, Ohio.

dispersion of Molykote Microsize particularly suited for extreme low-temperature applications, supplementing Molykote Type M-77 and Type U greases, as well as Molykote M-30, which are used for high and moderately low temperatures. (The Alpha Molykote Corp., LE-11/6, 65 Harvard Ave., Stamford, Conn.)

Cleanable Micronic Filter. Designed to remove micronic particles from large quantities of liquid, the newly-developed Super Auto-Klean filter stops all particles larger than 40 microns (which is sufficient for many systems), or in those cases where finer replaceable cartridge-type elements are used as secondary filters, greatly extends cartridge life (by preventing premature plugging of filtering surfaces in the secondary cartridge by removing all oversized particles and agglomerated contaminants.) Because of the unusually low pressure drop across the filter, flows can be handled in a space six times smaller than would a cartridge-type unit under similar conditions. Cleaning is done without stopping flow, simply by turning the handle, by hand, or motor drive; accumulated sludge may be drained off at convenient periods through the bottom drain plug. (Cuno Engineering Corp., LE-11/6, 4612 S. Vine St., Meriden, Conn.)

Fingerprint Remover. Especially useful in protecting highly-polished or super-finished surfaces from corrosion caused by the lactic acid, urea and sodium chloride residue of ordinary fingerprints, recently-developed Cosmoline 1070 fingerprint remover is particularly effective on non-ferrous metals and bi-metallic assemblies. In addition to meeting Government Specification MIL-C-15074A, other features include the rupture-resisting film it provides to allow safe handling of treated parts, easy removal by solvent prior to application of final finishes, non-toxicity, high anti-humidity properties, and long stability in storage. (E. F. Houghton & Co., LE-11/6, 303 W. Lehigh Ave., Phila. 33, Pa.)

Multiple Outlet Gear Pump. Available with from two to six outlets, the newly-developed multiple outlet gear pump (Model Z3U) features a divider device, controlled automatically, that enables each outlet to deliver an exactly-measured quantity of lubricant independent of the prevailing counter pressure. Utilizing a single pair of special-design gears to insure precision operation with minimum power consumption, the pumps are made in different sizes depending on the amount of lubricant required, and the delivery of the outlets can be equal or each one can be designed for a different quantity. Operating on a rotary drive with the direction of rotation being controlled by an adjustable sleeve on the drive shaft, the unit can be supplied with reversible drive for operation in both directions. (Nathan Mfg. Corp., LE-11/6, 45-02 Ditmars Blvd., Long Island City 5, N. Y.)

Coming Events

DECEMBER, 26-31, American Association for the Advancement of Science (National Meeting), Biltmore Hotel, Atlanta, Ga.

30, Mathematical Association of America (Annual Meeting), Rice Institute, Houston, Tex.

JANUARY, 9-13, 1956, Society of Automotive Engineers (Annual Meeting), Sheraton-Cadillac & Statler Hotels, Detroit, Mich.

23-25, American Society of Heating & Air-Conditioning Engineers (Annual Meeting), Sheraton-Gibson Hotel, Cincinnati, Ohio.

23-26, Plant Maintenance & Engineering Show & Conference, Convention Hall, Philadelphia, Pa.

23-26, Institute of the Aeronautical Sciences (Annual Meeting), Hotel Sheraton-Astor, New York, N. Y.

30 thru Feb. 3, American Institute of Electrical Engineers (Winter General Meeting), Hotel Statler, New York, N. Y.

30 thru Feb. 4, American Institute of Physics (Anniversary Celebration), Hotel New Yorker, New York, N. Y.

APRIL, 4-5-6, American Society of Lubrication Engineers (11th Annual Meeting & Exhibit), Hotel William Penn, Pittsburgh, Pa.

Subject & Author Indexes

These Indexes include the papers published in **Lubrication Engineering,** Journal of the American Society of Lubrication Engineers, in **1955;** Volume, (Number), and Page as indicated. To order back issues (80c each to members, $1.00 each to non-members), please indicate Volume and (Number), include remittance, and mail to: ASLE Publications, 84 E. Randolph St., Chicago 1, Ill.

SUBJECT INDEX

Adapting The Static Water Test To Research Methods, by E. J. Schwoegler & L. U. Berman ..11(6), 1955, p. 381

Atoms Trace The Wear, by W. R. Miller & H. R. Jackson .....11(4), 1955, p. 238

Cages For High-Speed Cylindrical Roller Bearings, by W. J. Anderson & Z. N. Nemeth .....11(1), 1955, p. 40

Deposit Analysis In Lubrication Problems, by P. B. Burgess & J. F. Wygant .....11(3), 1955, p. 193

Effect Of Air & Nitrogen Atmospheres On The Temperature Limitations Of Liquid & Solid Lubricants In Ball Bearings, by Z. N. Nemeth & W. J. Anderson .....11(4), 1955, p. 267

Effects Of Sliding Velocity & Temperature On Wear & Friction Of Several Materials, by R. L. Johnson, M. A. Swikert & E. E. Bisson .....11(3), 1955, p. 164

Evaluating Bearing Materials Under Boundary Lubrication, by B. Lunn .....11(4), 1955, p. 255

Evaluation Of Lubricating Grease Compatibility, by A. L. McClellan & S. R. Calish, Jr. .....11(6), 1955, p. 412

Factors Influencing Friction & Wear With Solid Lubricants, by M. B. Peterson & R. L. Johnson .....11(5), 1955, p. 325

Factors Influencing Humidity Cabinet Test Results, by H. A. Hartung .....11(5), 1955, p. 332

Fluids For The Grinding Of Titanium, by E. J. Krabacher .....11(6), 1955, p. 397

Foaming Of A Heavy-Duty Lubricating Oil, by W. M. Pugh & L. M. Tichvinsky .....11(1), 1955, p. 29

Friction & Fretting With Solid Film Lubricants, by E. E. Weismantel .....11(2), 1955, p. 97

Frictional Characteristics Of Plastics, by W. C. Milz & L. B. Sargent, Jr. .....11(5), 1955, p. 313

Glass Lubricant In The Extrusion Of Steel, by J. Sejournet & J. Delcroix .....11(6), 1955, p. 389

Grease Lubrication Dispensing Equipment, Its Operation & Application, by L. R. McDonald .....11(6), 1955, p. 402

Hermetically Sealed Refrigeration Compressor Lubrication, by K. Borah .....11(5), 1955, p. 319

Hydrodynamic Lubrication Of A Cam & A Cam Follower, by R. Davies .....11(1), 1955, p. 37

Influence Of Moisture On The Friction & Surface Damage Of Clean Metals, The, by R. O. Daniels & A. C. West .....11(4), 1955, p. 261

Integrally Sealed Ball Bearings, by L. D. Cobb .....11(5), 1955, p. 340

Interpreting Ball Bearing Damage, by B. J. Dempsey .....11(2), 1955, p. 91

Lubrication Application Problems In Coal Mining (Panel), G. R. Spindler, Chrmn. .....11(1), 1955, p. 46

Lubrication Problems In The Steel Industry (Panel), T. A. Marshall, Chrmn. .....11(3), 1955, p. 171

Maintenance Of Quality In Aluminum Sheet Rolling Oils, by J. O. McLean .....11(5), 1955, p. 337

Maintenance Of Water-Soluble Machining Coolants During Use, by J. A. Prevel .....11(3), 1955, p. 178

Neutrons, Gamma Rays, & Wear, by A. Hundere G. C. Lawrason & J. P. O'Meara .....11(4), 1955, p. 230

Oil-Soaked Felt-Pad Lubrication Of Ball Bearings At High Speed & High Temperature, by H. S. White, J. F. Swindells & Harriet V. Belcher .....11(3), 1955, p. 182

Radiant Heating Of Lubricating Oil, by R. H. Johnson .....11(1), 1955, p. 35

Recent Advances In The Hydrodynamic Theory Of Slider-Bearing Lubrication, by F. Osterle & E. Saibel .....11(3), 1955, p. 187

Recent Advances In The Lubrication Field, by B. B. Farrington .....11(1), 1955, p. 17

Significance Of Viscosity Studies Of Fluid Lubricants At High Pressures, by L. B. Sargent, Jr...11(4), 1955, p. 249

Simple Demonstration Of Flow Type In Grease, A, by H. E. Mahncke & W. Tabor .....11(1), 1955, p. 22

Sliding Friction Test For Metalworking Lubricants, by W. J. Wojtowicz .....11(3), 1955, p. 174

Small-Scale Laboratory Evaluation Tests On Synthetic Lubricants, by F. J. Watson.....11(2), 1955, p. 86

Soluble Oil—Handle With Care, by A. A. Manteuffel .....11(5), 1955, p. 309

Some Unusual Conditions Encountered In The Lubrication Of Rolling Contact Bearings, by T. W. Morrison .....11(6), 1955, p. 405

Some Viscosity-Shear Characteristics Of Lubricants, by E. E. Klaus & M. R. Fenske .....11(2), 1955, p. 101

What Happened To My Oil? by C. W. Nichols, Jr. .....11(4), 1955, p. 242

AUTHOR INDEX

Anderson, W. J., & Z. N. Nemeth: **Cages For High-Speed Cylindrical Roller Bearings** .....11(1), 1955, p. 40

Anderson, W. J. (See: Nemeth-Anderson) 11(4), 1955, p. 267

Belcher, Harriet V. (See: White-Swindells-Belcher) .....11(3), 1955, p. 182

Berman, L. U. (See: Schwoegler-Berman) .....11(6), 1955, p. 381

Bisson, E. E. (See: Johnson-Swikert-Bisson) .....11(3), 1955, p. 164

Borah, K.: **Hermetically Sealed Refrigeration Compressor Lubrication** .....11(5), 1955, p. 319

Burgess, P. B., & J. F. Wygant: **Deposit Analysis In Lubrication Problems** .....11(3), 1955, p. 193

Calish, S. R., Jr. (See: McClellan-Calish) .....11(6), 1955, p. 412

Cobb, L. D.: **Integrally Sealed Ball Bearings** .....11(5), 1955, p. 340

Daniels, R. O., & A. C. West: **The Influence Of Moisture On The Friction & Surface Damage Of Clean Metals** .....11(4), 1955, p. 261

Davies, R.: **Hydrodynamic Lubrication Of A Cam & A Cam Follower** .....11(1), 1955, p. 37

Delcroix, J. (See: Sejournet-Delcroix) ....11(6), 1955, p. 389

Dempsey, B. J.: **Interpreting Ball Bearing Damage** .....11(2), 1955, p. 91

Farrington, B. B.: **Recent Advances In The Lubrication Field** .....11(1), 1955, p. 17

Fenske, M. R. (See: Klaus-Fenske) .....11(2), 1955, p. 101

Hartung, H. A.: **Factors Influencing Humidity Cabinet Test Results** .....11(5), 1955, p. 332

Hundere, A., G. C. Lawrason & J. P. O'Meara: **Neutrons, Gamma Rays, & Wear** .....11(4), 1955, p. 230

Jackson, H. R. (See: Miller-Jackson) ....11(4), 1955, p. 238

Johnson, R. H.: **Radiant Heating Of Lubricating Oil** .....11(1), 1955, p. 35

Johnson, R. L., M. A. Swikert & E. E. Bisson: **Effects Of Sliding Velocity & Temperature On Wear & Friction Of Several Materials** .....11(3), 1955, p. 164

Johnson, R. L. (See: Peterson-Johnson) .....11(5), 1955, p. 325

Klaus, E. E., & M. R. Fenske: **Some Viscosity-Shear Characteristics Of Lubricants** .....11(2), 1955, p. 101

Krabacher, E. J.: **Fluids For The Grinding Of Titanium** .....11(6), 1955, p. 397

Lawrason, G. C. (See: Hundere-Lawrason-O'Meara) .....11(4), 1955, p. 230

Lunn, B.: **Evaluating Bearing Materials Under Boundary Lubrication** .....11(4), 1955, p. 255

Mahncke, H. E., & W. Tabor: **A Simple Demonstration Of Flow Type In Greases** .....11(1), 1955, p. 22

Manteuffel, A. A.: **Soluble Oil—Handle With Care** .....11(5), 1955, p. 309

Marshall, T. A., Chrmn.: **Lubrication Problems In The**

Steel Industry (Panel) .....11(3), 1955, p. 171
McClellan, A. L., & S. R. Calish, Jr.: **Evaluation Of Lubricating Grease Compatibility** .....11(6), 1955, p. 412
McDonald, L. R.: **Grease Lubrication Dispensing Equipment, Its Operation & Application** ....11(6), 1955, p. 402
McLean, J. O.: **Maintenance Of Quality In Aluminum Sheet Rolling Oils** .....11(5), 1955, p. 337
Miller, W. R., & H. R. Jackson: **Atoms Trace The Wear** .....11(4), 1955, p. 238
Milz, W. C., & L. B. Sargent, Jr.: **Frictional Characteristics Of Plastics** .....11(5), 1955, p. 313
Morrison, T. W.: **Some Unusual Conditions Encountered In The Lubrication of Rolling Contact Bearings** ....11(6), 1955, p. 405
Nemeth, Z. N., & W. J. Anderson: **Effect Of Air & Nitrogen Atmospheres On The Temperature Limitations Of Liquid & Solid Lubricants In Ball Bearings** ....11(4), 1955, p. 267
Nemeth, Z. N. (See: Anderson-Nemeth) ....11(1), 1955, p. 40
Nichols, C. W., Jr.: **What Happened To My Oil?** ....11(4), 1955, p. 242
O'Meara, J. P. (See: Hundere-Lawrason-O'Meara) ....11(4), 1955, p. 230
Osterle, F., & E. Saibel: **Recent Advances In The Hydrodynamic Theory Of Slider-Bearing Lubrication** ....11(3), 1955, p. 187
Peterson, M. B., & R. L. Johnson: **Factors Influencing Friction & Wear With Solid Lubricants** ....11(5), 1955, p. 325
Prevel, J.: **Maintenance Of Water-Soluble Machining Coolants During Use** .....11(3), 1955, p. 178
Pugh, W. M., & L. M. Tichvinsky: **Foaming Of A Heavy-Duty Lubricating Oil** .....11(1), 1955, p. 29
Saibel, E. (See: Osterle-Saibel) .....11(3), 1955, p. 187
Sargent, L. B., Jr.: **Significance Of Viscosity Studies Of Fluid Lubricants At High Pressures** ..11(4), 1955, p. 249
Sargent, L. B., Jr. (See: Milz-Sargent) ..11(5), 1955, p. 313
Schwoegler, E. J., & L. U. Berman: **Adapting The Static Water Drop Test To Research Methods** ....11(6), 1955, p. 381
Sejournet, J., & J. Delcroix: **Glass Lubricant In The Extrusion of Steel** .....11(6), 1955, p. 389
Spindler, G. R., Chrmn.: **Lubrication Application Problems In Coal Mining** (Panel) .....11(1), 1955, p. 46
Swikert, M. A. (See: Johnson-Swikert-Bisson) ....11(3), 1955, p. 164
Swindells, J. F. (See: White-Swindells-Belcher) ....11(3), 1955, p. 182
Tabor, W. (See: Mahncke-Tabor) .....11(1), 1955, p. 22
Tichvinsky, L. M. (See: Pugh-Tichvinsky) ....11(1), 1955, p. 29
Watson, F. J.: **Small-Scale Laboratory Evaluation Tests On Synthetic Lubricants** .....11(2), 1955, p. 86
Weismantel, E.: **Friction & Fretting With Solid Film Lubricants** .....11(2), 1955, p. 97
West, A. C. (See: Daniels-West) .....11(4), 1955, p. 261
White, H. S., J. F. Swindells & Harriet V. Belcher: **Oil-Soaked Felt-Pad Lubrication Of Ball Bearings At High Speed & High Temperature** .....11(3), 1955, p. 182
Wojtowicz, W. J.: **Sliding Friction Test For Metalworking Lubricants** .....11(3), 1955, p. 174
Wygant, J. F. (See: Burgess-Wygant) ....11(3), 1955, p. 193

Plan NOW to attend the

11th

ASLE

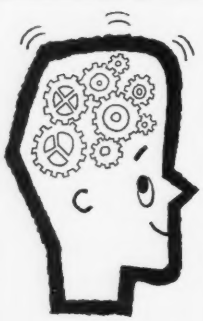
Annual Meeting & Exhibit

Hotel William Penn, Pittsburgh

April 4-5-6, 1956

Advertisers' Index

Acheson Colloids Co. 437
Alemite Div., Stewart-Warner Corp. 377
Alpha Molykote Corp., The 369
American Potash & Chemical Corp. 372
Atlantic Refining Co., The 433
Baroid Div., National Lead Co. .....424 & 425
Bel-Ray Co., Inc. 376
Brooks Oil Co., The 366
Burns Laboratories, Inc. 426
Carbide & Carbon Chemicals Co. 431
Cuno Engineering Corp. 370
Farval Corp., The .....(Inside Back Cover)
Foote Mineral Co. 419
Garlock Packing Co., The 373
Grafo Colloids Corp. 363
Hercules Powder Co. 379
Hodson Corp., The .....(Back Cover)
Houdaille-Hershey of Indiana, Inc. 423
Houghton & Co., E. F. 421
International Lubricant Corp. 434
Ironsides Co., The 436
Lincoln Engineering Co. 435
Lithium Corp. of America, Inc. 429
Lubriplate Div., Fiske Bros. Refining Co. 438
Madison-Kipp Corp. 368
Manzel Div. of Houdaille-Hershey Corp. 428
Morgan Construction Co. 362
Norgren Co., C. A. 427
Polymer Corp. of Pennsylvania, The 378
Shell Oil Co. 364
Sinclair Refining Co. 422
Sun Oil Co. 374
Trabon Engineering Corp. .....(Inside Front Cover)



creativity?

Chemistry and Physics —Pure and Applied
Process Engineering
Mechanical Analysis, Design and Development
Metallurgy
Electronics Research
Petro-Chemical Technology
Food and Flavor Research
Biology
Operations Research
Industrial Economics and Management Services
Regional Development

No bars or shackles or preconceived notions of doing things restrict your imagination and resourcefulness in tackling an assignment at ADL.

The creativity of the individual to find sound, practical solutions for a wide variety of industrial problems is what has made ADL one of the best-known private industrial research laboratories.

There are OPENINGS NOW at ADL which offer unlimited opportunity for men with university training and appropriate experience. Your inquiry will receive prompt, individual attention.

Write To
Personnel Director — Professional Staff
Dept. 22

Arthur D. Little, Inc.
Established 1886
28 Memorial Drive
Cambridge 42, Mass.

No stoop, no squat, no oil can to lubricate 24 bearing surfaces on this connecting rod balancer

FARVAL—
Studies in Centralized Lubrication
No. 177

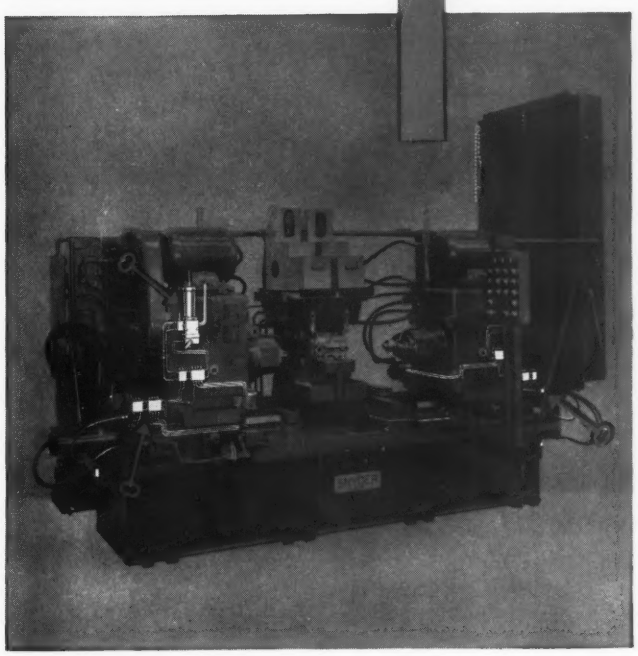
THIS machine balances the connecting rod used in the V-8 engine of a well-known American automobile. As shown in the photograph, 24 rotating and sliding bearing surfaces are lubricated by a Farval manually operated system of centralized lubrication.

Not only does adequate lubrication protect the bearing surfaces, keeping the balancer always in perfect working order, but it also saves oiling time, labor and lubricant. A few strokes of the pump handle periodically, by the regular machine attendant, delivers a measured amount of lubricant to each bearing surface. Failures just don't happen. Oil cans and grease buckets are eliminated and oilers can be put on other productive work.

Farval is the ideal system of centralized lubrication for industrial machinery and other equipment, especially where uninterrupted operation is important. Farval can be installed easily and inexpensively on almost any machine at any time —either by the builder when new or on an older machine by the owner. Experience shows that a Farval system, manual or automatic, usually pays for itself in a very short time in the savings it effects in bearing expense, labor, lubricant and elimination of interruptions to production.

Farval engineers are at your service—to analyze your lubrication problems and advise on the application of modern centralized lubrication systems to the equipment you build or buy. Write us and our representative will call. Or ask for Bulletin 26. The Farval Corporation, 3267 East 80th Street, Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.



KEYS TO ADEQUATE LUBRICATION—Wherever you see the sign of Farval—the familiar central pumping station, dual lubricant lines and valve manifolds—you know a machine is being properly lubricated.

The connecting rod balancing machine shown above is fully automatic in all its phases, except for loading and unloading of the part, which is done by the machine operator who also operates the Farval pump once or twice per work shift. Photograph by courtesy of the builder—Snyder Tool & Engineering Co., Detroit, Mich.

ATTENTION

WHEN "RUN OF REFINERY"

PRODUCTS WILL NOT DO

Call

HODSON

The HODSON CORPORATION

Lubrication

5301-11 West 66th Street

CHICAGO 38, ILLINOIS

Decatur, Ill.

Detroit, Mich.

Pittsburgh, Pa.

Philadelphia, Pa.

Montreal and Three Rivers, Quebec

11-12-L-55

Printed in U. S. A.